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BY

J. W. THOMAS, F.I.C., F.C.S.

SCIENTIST IN VENTILATION AND HEATING

AUTHOR OF "THE VENTILATION, HEATING AND MANAGEMENT OF CHURCHES AND PUBLIC BUILDINGS"; "COAL, MINE-GASES AND VENTILATION," ETC.

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1906

LELAND STANFORD JUNIOR
UNIVERSITY

PREFACE.

AMONG the very favourable notices accorded to the previous treatise on the *Ventilation, Heating and Management of Churches and Public Buildings*, none was more greatly appreciated than that which termed it "Common Sense applied to Ventilation". The author will be well satisfied if the present work is as favourably received, and has done his best to make it worthy of such a title.

Much scientific information in reference to the composition of the atmosphere and other technical matter of a theoretical character might have been incorporated, but it was thought best to omit these and all historical associations with a view to provide a treatise of reasonable compass which the architect, builder and tenant might consult for practical purposes. The student of ventilating science can obtain theoretical physics more clearly and fully treated in several works on the subject, but it is hoped that the present treatise will enable the ventilating and heating engineer, as well as the occupier of a house, to see that when natural philosophy is correctly applied the result is exact and satisfactory.

The terms "wind suction" and "wind aspiration" mentioned frequently in this treatise to explain the lesser volume of air which gets into a room owing to the reduced

87588

pressure and expansion of the air caused by the velocity of the wind blowing outside, do not convey the exact meaning of the operation involved. It is the elastic property of air which enables the flowing wind to "drag" and expand the air in its wake so preventing much from passing through the crevices around windows, doors, etc. The "elastic drag of the wind" explains the action more correctly but less clear to the reader, perhaps, so that "wind suction" and "wind aspiration" have been used throughout for want of better terms.

The deductions drawn and the hints given, as well as the objections raised to the methods widely adopted in fixing radiators, or to their form and position, are not theoretical, but are either obtained from the experience of the writer or from experiments which he carried out with the apparatus in question.

The ground covered by the term dwelling is very wide, because it must include the castle as well as the cottage, and, whilst the chapters on ventilation, heating and lighting have a general bearing upon the whole area, the apparatus described is specially applicable to the suburban villa and to houses in large towns.

In conclusion, all the subjects have been faithfully dealt with on scientific and practical lines, and, as no advertisements have been accepted, nor any remuneration from manufacturers, the weak points in the appliances used in dwellings have been freely criticised, and no one's goods eulogised to the detriment of those of equal, or perhaps greater, merit produced by other makers.

OVERDALE, SHORTLANDS,
KENT, 1906.

CONTENTS.

LIST OF ILLUSTRATIONS.

CHAPTER I.

PHYSICAL LAWS BEARING UPON THE SUBJECT.

THE air in a house with closed doors and windows would be for the most part in a state of equilibrium, unless some natural or artificial aid was afforded to cause circulation. In the open air, the winds and the unequal heating of the sun's rays give rise to much movement and admixture, whilst the bodies of men and animals in winter and cool weather are heaters of considerable value, creating upward currents which add to the buoyancy of the breath exhaled. These are the natural forces which cause the circulation of air and prevent stagnation, and are generally regarded as the results of increased temperature, primarily. Winds are usually attributed to the unequal heating of the earth's surface by the sun, but it is becoming more certain, as the writer has pointed out elsewhere, that electrical action has not a little to do with the forces exerted by tornadoes, and probably also with much less violent movements of air. These electrical excitements may be disregarded in dealing with the ventilation of dwelling-houses, but in all cases referring to air movements in the open atmosphere they are of much interest, and further knowledge upon the subject will be most welcome (see Appendix No. 1). Previous to and during a thunderstorm the electric conditions of the air both in the open and in a dwelling exercise considerable influence upon the breathing organs and upon the economy generally, but this state of things requires electric discharges in the near neigh-

bourhood for its removal. The ionisation of air is referred to in the Appendix, No. 1.

In a dwelling with doors and windows closed, the air is much confined, and during that portion of the year when the temperature outside is too low to admit of the windows being open with comfort, and too high to necessitate a fire, the only force available, apparently, for ventilating our living-rooms is the heat of our bodies and breath by day, and the assistance of the heat of the illuminants by night. This is not altogether true, however, because the winds and air movements outside always exercise more or less influence—as will be noticed in the next chapter—and the unequal heating of the sun's rays upon the house and windows may be utilised for the purpose of ventilation. Furthermore, the kitchen fire always "pulls" upon the internal air of the house, and, notwithstanding the chief inlet air supply and the path of the less resistance may be down the stairs from the bedrooms, all the air in the rooms will be influenced whether the kitchen is on the ground floor or in the basement, unless of course the kitchen is entirely cut off from the other portion of the house. The heat evolved by one human body together with that present in the exhaled air is sufficient to raise the temperature of a room 12 feet square from 45° to 48° F. in two hours, if the window space is not excessive and there is no window or door open. Four persons will cause the temperature of such a room to rise from 55° to 60° F. in one hour. The heat evolved by illuminants, especially when gas is consumed in ordinary burners, soon raises the temperature of a room at night, and it is then that the need of ventilation is most felt. If the temperature of a small room in which a fire is burning is 60° F. when the gas is lit, and the room is then occupied by four or more persons, it rapidly rises to 70° F. unless the door or window is opened. It will be seen, therefore, that the heat obtained from these two sources can be utilised to ensure ventilation. On the other hand, a similar room which is at

60° without fire is rendered very close and oppressive when several persons are present and there are two or three gas-lights burning.

The unequal heating of the sun's rays upon the house and windows is a subject well worth studying, and is one, so far as I am aware, which has never received due recognition as a ventilating agent in our dwellings. During a considerable period of the year when no fires are lit, and especially during the months when the air is moist and raw, the inmates of a house congregate in order that the warmth of their bodies shall make the temperature of the room more pleasant and bearable. From what has been said, it will be seen that the air in a small room heated by human bodies and breath and by illuminants becomes very foul and polluted when the temperature of the air outside is 55° F., and if the fire is lit, the atmosphere is soon made very hot and enervating. It often happens that the aspect of such a room is north, and not unfrequently the dwelling is a small villa having a drawing-room in front of fair dimensions, whilst the back sitting-room is the one in question —the room generally occupied in the daytime by the family. Is it pride or sheer stupidity which makes the housewife keep the only good living-room in the house for show? into which a few callers are admitted, and in which no fire is lit in the winter sometimes for weeks together! A number of children, perhaps five or more, are crowded into the small room in cold weather, because there is a fire, and the large room is unoccupied. Parents who realise the responsibility for the health of their children will quickly alter this state of things. The living-room will be the largest in the house, and if possible facing the morning sun. This is the room in which fire will be lit daily in cold weather, and, having pocketed pride, it is here the visitor will be asked to wait until the lady dresses herself to receive the caller—instead of sitting in a room so frigid as to give rise to bronchitis or pneumonia. It may be asked, however, since half the houses in a street must face the

opposite way, what is to be done if the aspect of the larger room is north? Without hesitation, both rooms should be used, and no show-room kept if there is a family of children, otherwise a small room can be made comfortable for two. The large room should be used at night in winter and cold weather—the small room in the late spring, summer, and the early autumn during the daytime. The above remarks apply to a small villa occupied by one family, and where the two rooms on the ground floor are used a temptation frequently occurs in such cases to make a drawing-room out of the largest room on the first floor to be preserved chiefly for show purposes. If there is a family no consideration of that kind should prevent the room being used either for the parents' bedroom or for the nursery. For the latter a sunny room is most beneficial, and it should not be situated in a garret beneath a roof which becomes very hot when the sun shines upon it.

The heating effects of the sun in the late spring and early autumn upon rooms without fires are very appreciable. In a room with two large windows I have seen the temperature rise from 55° to or over 60° F. in less than an hour. Under these circumstances pressure is exerted on the outside of the door of the room and a current of air immediately begins to pass underneath, showing that the sun has caused a circulation of air in the room and so assisted ventilation. If one or more of the windows of a house facing north-west or north is opened upstairs and the kitchen door leading to the hall is shut, the opening of the door and window in a sitting-room having a south aspect will enable a strong current of air to sweep through the room and ventilate it after a morning meal. When the evening sun shines upon a north-west window which is opened a little at the top—the door also being open—and the door and window having a south or south-east aspect upon the same floor are likewise open, a slight current of air may be caused to flow in the spring and autumn from south to north when no fires are lit, and when the outside temperature is about 55° F.

The heating effects of the sun are so manifest in summer as to be noticed by all, and the rooms facing south are known to be hot in consequence; but, notwithstanding all this, the atmosphere in a room just warmed by the morning sun is exhilarating, and it is cooler in the evening than that upon which the sun has just been shining.

If the bulb of a thermometer is held so that the sun's rays fall upon it, it will show a much higher temperature than if it were held in the shade. The radiant heat of the sun's rays is absorbed by the bulb of the thermometer, and the temperature rises. This is why the temperature is said to be perhaps 100° F. in the sun when it is only 70° in the shade. Not only glass, but most solid matter absorbs radiant heat, and thus becomes hotter than the surrounding air which absorbs it less readily. The walls, glass, earth and other matter upon which the sun shines not only absorb radiant heat, but give up this heat to the air which is warmed by convection, *i.e.*, the air next the heated material becomes itself heated and rises, giving place to cooler air which in its turn is heated and rises also. If there is a difference of 30° between the temperature in the sun and the temperature in the shade it will be seen that the force for ventilating or moving air is considerable, but the difference shown between one thermometer in the sun and another thermometer in the shade situated within two or three feet of each other in no way represents the full power of the sun and the shade when the sun is shining at one side of the house and the shade or shadow is upon the other side. It rarely happens that the effects of the morning sun are sufficiently hot in this country to make us study how to cause a breeze of air to pass through the room which faces east, south-east or south, but by opening a door or one or two windows on the other side of the house it is quite possible to send a current through the room in question which has its door and window open also. Towards mid-day there may be no part of the house in shade, but the north side will not have had its walls heated by the sun's rays so hot as

those on the south side, and a slight current of air may still be caused to flow through the house from north to south. At this time of the day, however, the windows are best kept closed especially if there are outside blinds in position.

If the house is surrounded by trees, the effects of sun and shade may not be very apparent because it is nearly all shade in the morning and evening. In this case, however, water evaporated from the earth and from the vegetation passes into the air as water vapour or steam, and, in the act of vapourising, it takes up and renders latent a large quantity of heat. This heat is abstracted partly from the earth and partly from the air and vegetation in the immediate neighbourhood so that much cold results, and the air in contact with the cooled surfaces is itself cooled and becomes considerably heavier, the consequence being that by reason of its greater density it displaces the warmer atmosphere and flows into the living-rooms of the house which are rendered deliciously cool. It is this evaporation of water and the greater density of the air resulting from the cooling effects produced which enable the sun and shade *combined to be a greater power for ventilation than a simple reading of the thermometer in the sun and the other in the shade close at hand would lead one to expect.* When the sun shines upon the grass or moist earth, evaporation proceeds more quickly than in the shade, but the latent heat absorbed in the process is largely supplied by the sun's rays. Under these circumstances the lesser density of water vapour compared with that of air tends to make the atmosphere, which has received extra moisture, ascend quickly, and affords ventilating power to the cooled air in the shade which hastens to take the place of the warm air that has gone upwards, if any free passage is afforded it. If there are no trees near, the portion of the house facing west will be most warmed by the afternoon sun, and the east and south-east will be in the shade. If the living-room to be occupied that evening is on the north-west or west side, it should be kept as dark as possible, carefully preventing the sun's rays

from falling upon the furniture and other solid matter in the room, otherwise the radiant heat will be absorbed and afterwards given off to heat the room. Later on the window should be so open that the woodwork of one sash covers the other. The door should be open also, as well as any door or window on the shady side. As indicated already it is not only the absence of the sun's rays which supplies the moving forces to the air in the shade, but it is the continual evaporation which so lowers the temperature of the air that it is caused to flow through the house to supply the place of what has been heated by the sun's rays and by convection. A continuous breeze can thus be kept up, flowing from the shady to the sunny side, and this breeze is much more refreshing than that given by a table fan, as the air from without has had its electro-static condition altered by the withdrawal of heat which has been rendered latent.

In the foregoing pages a question has been more or less answered—in a piecemeal fashion—which is of much interest to those who live in England, although it more especially concerns the inhabitants of the "Sunny South," of India and of other warm climates—"What is the best way to keep a house cool in summer?" Is the Italian or East Indian right in placing lattice blinds outside his windows, rendering the rooms dark and leaving no window open? Woodwork or blinds of any non-metallic material do not absorb radiant heat nearly so much as glass which is indeed a very effective absorbent. Furthermore, the glass in windows is always more or less uneven, giving rise to the dispersion or concentration of the sun's rays passing through it, and reflecting some in every direction, and more or less adding extra heat to the air in the room. If the window is not protected by some form of blind on the outside, so shielded at the ends that no rays can penetrate and no light be reflected, it is impossible to prevent the glass of the window giving rise to much heat whilst the sun is shining upon it. No inside blind, however coloured, will prevent much of

this heat becoming effective, and some sunlight, often a great deal, will be deflected from the glass through the openings on the sides of the blinds and so add to the heat of the room. A good lattice or other blind on the outside which will thoroughly prevent the sun's rays reaching the window is most desirable. The question may be asked, "Should this blind be so constructed that all the diffused light possible shall enter the room only excluding the sun's direct rays?" For the purpose of killing germs in bedrooms a little warm sunlight is efficacious, and this should be obtained before 10 A.M. in the summer; but, although the heating effects of deflected and diffused sunlight[1] have not been recognised hitherto, they are very appreciable, and it is almost impossible to prevent them altogether unless light is *entirely* excluded. Many modern churches which have stained glass windows are remarkably cool in summer compared with other buildings, and this is not in consequence of the walls being very thick like they are in those churches of older date, but is due to the fact that little light gets into them and that the direct sunlight is filtered through coloured glass which prevents the heat rays passing. *To keep a room cool in summer it is best made as dark as possible.*

Now as to currents of air, should the windows be open when the outside blinds are down? We have seen that if the north windows are open a current of air will travel from them

[1] The sun's rays falling upon the surface of a pond affords a good illustration of the heating effects of reflected and diffused sunlight. It has been shown that the evaporation of moisture causes much cold, and persons in a boat on the water would be chilled by the rapid withdrawal of heat from the air immediately above the water were it not that the sunlight is reflected by the water and diffused by every irregularity of the surface. The sun's rays so thrown back warm the moist air from which the heat rendered latent has been absorbed and tempers it, so that it is not raw or unpleasant. If the reader has noticed how chilly the surface or margin of a pond becomes when the day has been hot and the sun has been suddenly hidden by a cloud, he will appreciate the heating effects of reflected and diffused sunlight.

towards and through the south windows in the morning, and *vice versa* in the late afternoon. In the morning before 10 A.M. the air moving from the north windows towards those on the south side will purify the rooms, and, in this country, lead to little extra heating. During the day from 11 A.M. to 3 P.M. all the windows should be closed and the rooms kept as dark as possible excepting the attic windows which should be open all day unless the roof is of straw and thatched. Through these a current of air will travel from north to south in the morning and south to north in the evening, and the mid-day sun will so heat the roof, especially if it is slated, that the air outside will be less hot than that in the rooms next to the roof; and the closing of the attic windows would consequently add to the heating effects.

The foregoing remarks upon the heating effects of the sun refer chiefly to detached and semi-detached houses, and to those in streets running east and west where there is a free way for air to pass from the north windows to the south by simply opening doors. But there are blocks of tenements facing north-west and south-east in which, unfortunately, the rooms occupied by the family all face one way, and there is no open passage between the tenement with the north-west aspect and the one with the south-east aspect, but simply a parting wall—the entrance being at one end of the little flat. In tenements so arranged there is no chance to get a current of air to move in summer time, and the pent-up, roasting atmosphere can be better imagined than described. It is a pity that those who have the providing of such homes for the poor do not exercise a little common-sense in the matter, because any other method of arrangement of the flats would enable the occupants to get a breath of air. When the sun sinks on a hot summer day the flats on the north-west are simply ovens, and there is little wonder that men feel compelled to walk miles to open spaces like Hampstead Heath to obtain sleep which it is almost impossible to get in the tenement. It is extremely difficult to

ventilate small rooms in any position, but, unless every facility is afforded, it is impossible to make those sanitary in the summer in which no fire has burned during the day-time. Where the poor herd together in single rooms, the one room is both kitchen and bedroom, and a fire is lit every day. This adds to the heat in the day-time, but at night, both in summer and winter, much air is forced into the room and up the chimney-flue, and the occupants are considerably better off than are those who sleep in a small room in a tenement which has had no recent fire and upon which the sun has shone with all its power before it sank below the horizon.

In a previous treatise it was pointed out that the effects of wind require careful calculation in considering the sites for public buildings, and that such considerations were neglected. In like manner in the arrangement of flats, small or large, and tenements, the aspects of the building should be carefully noted, and the plans drawn accordingly, so as to get all the ventilation possible by natural agencies; but this has been frequently forgotten hitherto, and in some cases apparently not even thought of.

The unequal heating of the sun's rays gives rise to the breezes which blow in summer. The change of direction which these latter take in consequence of the hills and valleys being heated by the sun's rays, or because of their being shaded from them, gives rise to varying currents, and an intensely close warm atmosphere may be caused to follow and occupy the place of a cool and denser one which has moved forward to sweep out and upward the air in a warm, sunny basin or valley. When such an atmosphere surrounds and gets into the house it frequently has the same effects upon the human economy as are experienced during a thunderstorm, so that one is led to think such results must be due to some electric condition of the air. When air is very hot and moist, however, distressing feelings are always experienced, and these are due to the fact that the moisture exuded from the pores of the skin is not at

once removed by a moisture-laden atmosphere, and the skin becomes moist and clammy. This hot, moist air which has taken the place of air that was cooled is lighter, and as it surrounds the house and is drawn in by the heavier air flowing out, it finds the *interior brickwork in a cooler condition than it is itself.* The consequence is, that as the air is drawn into the flues of those chimneys where there is no fire, it is cooled somewhat and becomes heavier. This denser air tumbles down the chimneys and makes its way into the rooms below, thus establishing a down current. This explains why it is that the smell of tarry soot is sometimes, and, in some situations, frequently, smelt in the living-rooms in summer. Where the ground in the immediate neighbourhood favours the formation of these hot spells of moist air, the housewife should be careful to have the chimneys *well* swept after fires have been given up in the spring-time. In a drawing-room where the smell is persistent and frequent, and it is going to be used for a state occasion, a Japanese fan can be spread in front of the grate-opening to close it as much as possible, but *leaving the register open*, and a small oil lamp placed behind this fan in the grate. Such an arrangement will prevent the air descending and the nauseous smell also.

TEMPERATURE.—The foregoing considerations partly deal with temperature—with heat and cold—but the question as to the best temperature to maintain in our dwellings during weather when it can be more or less controlled will next have attention. The fresh-air craze so recently advocated and adopted for the cure of consumption is fast losing its hold upon the community, and this is only what was expected by most people. No one will deny the need of good ventilation and of more fresh air than is generally admitted into our dwellings, and especially our living-rooms; but there is no question that a feeling of comfort is of much more value to one sitting for hours in a living-room than is a decrease of ·1 per 10,000 in the carbonic acid. Whilst on this subject, a word of caution is

necessary to those who sleep in the winter with the windows considerably open. Consumptive patients not unfrequently sleep upon open balconies facing south or south-west in winter, but by common consent the buildings are placed near the top, or on the crest of a hill. This is well, although the reason why, apart from the greater air movement, is not generally if at all known, but in the evening and night-time there is frequently a change of air current, and now and again the air from the upper regions in its dry and frigid condition presses down to the earth. The velocity of the air currents moving near the earth, and their greater density proportionately, prevent the upper air generally flowing downwards, because the barometric pressure decreases as we ascend; but this descent of cold air does sometimes occur towards evening and in the night. The warmest air is in the valleys, and when these currents descend it is into the valleys they pour. Those who will imitate the patients sleeping in the open had better remember that this frigid atmosphere from above has a most deleterious action upon the breathing organs, giving rise to chill, inflammation of the lungs and bronchitis. The effects are the same as when one descends into a cold crypt or dungeon, only that the person sleeping has far less vitality to resist the action of the sudden inrush of frigid air. Although a hill-top is colder than a valley—*i.e.*, its actual temperature is colder—the air is not susceptible to such sudden variations, and those who live in valleys and sleep in rooms with north or north-east aspects will be well advised to be careful that, in seeking to obtain fresh air, death or permanent injury may not come in through the window. The head of the bed is best placed as far as possible from the window, so that cold air flowing in shall diffuse and become more or less warmed before it reaches the lungs. In the foregoing remarks it has been assumed that no fire has been lit in such a bedroom. If there is a fire it will cause much air to come in and ventilate the apartment, even if the door and window are closed. No warm or vitiated air will escape through the

top of the open window unless it is much lowered, because the fire will take its supply along the lines of the least resistance. If the weather is very cold the window had better be closed. With regard to the best temperature for a bedroom in winter, it has been contended that the colder the air is the more oxygen it contains, and this is true. The same persons, however, would extol the health-giving properties of mountain air, providing the altitude was not above 5,000 ft. Now there is far less oxygen in one cubic inch of air at 32° F. on a mountain 4,000 ft. high than there is in air at 62° F. near the sea-level, because the mountain air is rarefied. The question of the amount of oxygen may therefore be set aside. In determining the temperature of the air for a bedroom three points have to be considered. 1. The room should be sufficiently warm for the sleeper to require little weight of clothing. 2. The air should not be too warm to allow the removal of moisture from the skin as soon as it is exuded. 3. The room should be as warm as Nos. 1 and 2 will allow, so as not to throw extra work upon the lungs and blood in maintaining the temperature of the body. A temperature of 55° to 60° F. fulfils Nos. 1 and 2 admirably, and answers No. 3 much better than a lower temperature.

The best temperature for the sitting-rooms is 62° to 63° F. Those who suffer from cold extremities may like 64° or even 65° better, whilst others with good circulation and much vitality prefer 60° F. It will be seen that the range of temperature is therefore very small. The experience of those who have had to do with the ventilation of the House of Commons proves that air at 62° to 63° F. is what suits the majority of the members, and the author has noticed from repeated and frequent observations in his own home, which is heated with hot water, that 62° is a temperature generally enjoyed by the family for the sitting-rooms. For a billiard-room where active play is going on 60° F. is pleasant, and the drier the air in reason the better—60 per cent. of saturation by aqueous vapour being

very satisfactory. A temperature anything above 65° in winter in our living-rooms feels enervating, and if the moisture from breath or from that of burning gas as an illuminant is largely present the feeling of depression and enervation is vastly increased. When a number of persons occupy a small room having a fire and gas-lights burning, it soon becomes very hot, and the door or window, notwithstanding the draught, has to be opened. The feelings experienced are usually the thermometer in most households, but these rarely indicate the extent of the pollution until the mischief has assumed bad proportions. The consequence is that the air in the room has been allowed to become much too hot before the window or door was opened, and so cause the draught to be more pronounced and intolerable than would be the case if the admission of cold air was made when the temperature of the room was 5° less. A thermometer only costs a shilling—a reliable instrument too—and if one is provided in every sitting-room, and indeed in every bedroom also, it will well repay the trifling outlay. A thermometer should be regarded as part of the necessary furniture of every room. Where one is in position, it is surprising how often it is consulted, and there is no question that its presence adds much to the care with which the ventilation of a room is looked after—and this the author can vouch for from his own experience.

Ventilating Pressure.—Wherever there is friction encountered, and there always is when air is moving either upon itself or against the surface of inlets, the edges of doors and their frames or the edges of windows and their frames, and a fire is burning in a room and the doors and windows are shut, the difference of pressure upon the air in the room and that upon the air outside at the same level is very appreciable. If the window is opened as fully as possible, there will usually be a slight difference of pressure—a lesser pressure in the room than there is outside—whilst in cold winter weather (with windows and doors closed) the difference is often sufficient in

small rooms to cause the air to travel under doors and around windows and through every available chink at so high a velocity as to make the draughts intolerable. The larger the room the less will these movements of air be noticeable, but the partial vacuum will be the same, providing a similar volume of air gains access from without, and the "pull" of the chimney is the same in either case. Since the fire creates a partial vacuum in a room no more air can be drawn or driven out either at the same or a higher level than the fire, without first *overcoming the exhaust power of the fire*, and if this is done it *means that the chimney must smoke*. It is scarcely possible to conceive that in the twentieth century it is necessary to refer to the reduced pressure in a room where a fire burns, but air-shafts are still built alongside chimney-flues with the expectation that they will extract air *from* the room and assist the fires in ventilating. This matter is further mentioned in chapter v. The question may be asked, however, "Is it not possible by the use of sufficient ventilators in the outer walls to bring the pressure in a room high enough to cause separate air-shafts between the flues to operate?" The answer is that it can rarely be done with comfort in a reasonably sized living-room, and that the temperature of the smoke and air in the chimney would be so greatly lowered that the heating effects upon the air-shafts would be much reduced also. If the flue is in the inner walls and has a "good draught," the ventilation of the room so far as the withdrawal of foul air is concerned can be accomplished much better by a sensitive chimney-breast ventilator. If the flue is in an outer wall, cold and damp, attempts to use open ventilators and increase the pressure up to that on the air outside will only cause the current of air and smoke ascending the chimney to be cooled further, and the ventilating power of the chimney will be so much reduced that the suction upon the ventilators and crevices around windows caused by a swirl of the wind near the ground outside would immediately overcome the upward draught in the chimney and cause the fire to smoke.

As will be further pointed out in the next chapter, it is not wise to have *too much* air provision in rooms which have cold chimneys in outer walls.

These considerations lead up to the question of ventilating force and to how one can calculate the ventilating power of a chimney, and determine how much of this is lost in friction by reason of the air being forced through small crevices between window sashes and their frames and between doors and their frames as well as the loss due to friction through the air and smoke rubbing against the sides of the chimney-flue. It would be a great boon to the builder as well as to the occupier if there were some ready means of estimating the ventilating power of a chimney, and if it were possible to give a minimum ventilating force for every chimney, then by simple calculation it could be at once seen whether it possessed the necessary power or draught. For those who wish to calculate ventilating pressure, figures and tables are given in the appendix; in the text, however, except where it is necessary to show how certain physical laws operate, calculations of ventilating power will be dispensed with, for the simple reason that they are not possible in practice, and, therefore, waste of time to indulge in them. If it is a question of draughts which the client wants remedying, it may be concluded that the ventilating power of the chimney is ample and that the incoming air requires distributing, or the volume escaping may require to be moderated if the chimney is very high. If, however, the chimney smokes, it is not by any means an easy matter oftentimes to estimate whether the ventilating power of the chimney is sufficiently potent should the flue be in the outer wall, as there are so many points which have to be considered. For instance, want of a proper damp course, use of salt-water sand in the brickwork, the aspect of the wall in which the chimney is built, the size of the flue, proximity of other houses, effects of winds and many other considerations, all of which have to be taken into account. It may usually be concluded that where the velocity of the smoke entering the

chimney is 5 feet per second when the doors and windows are shut the ventilating power of this flue is satisfactory, and the volume of air coming into the room reasonably large, but if that velocity has been taken when the temperature outside was below 35° F. and when the prevailing and most troubling winds were *not* blowing, things may be, and often are, very different at higher temperatures when choppy and severe or gusty winds are prevalent. Again, the want of this velocity of 5 feet per second in the smoke above the fire is no proof that the ventilating power of the chimney is deficient. Some small rooms with large flues, having doors and windows very close-fitting, show a great want of air, and the velocity is reduced in consequence. If the door or window is opened somewhat, the velocity will be increased, revealing the fact that the chimney draught is ample, and not unfrequently in very high buildings even excessive. Furthermore, it is possible that on one side of a house on the ground floor where three fires perhaps are burning in rooms adjoining each other, the velocity of the air in the chimneys is very small indeed, whilst one smokes badly during rough winds. This state of things may not be due, and often is not due, to lack of ventilating power, but to the fact that the air supply in that part of the house is not sufficient to feed more than two chimneys. This is proved to be the case, for when two fires only are alight, there is a good velocity in the chimney-flues and no down-draught. In public buildings set apart for offices, it frequently happens that the air getting into a suite of offices will not support the three fires. The ventilating power of one chimney may be overcome owing to the position the top of the chimney occupies upon or under a roof. Let not the reader conclude that the difficulties of this subject are unduly magnified, or that the mystery of variations in ventilating pressure might be clearly elucidated, for such is not the case. This question is beset with so many complications that unless one fully conversant with them all considers them on the spot, it is almost impossible sometimes to determine what is really happening.

It will be best to consider the physics of ventilating pressure a little closely so as to grasp certain facts bearing upon the subject—facts which fortunately are exact and invariable, for the physics of this subject, mysterious as it has manifested itself, are as certain as mathematics; and ventilation will prove to be an exact science when we know all the side issues which interfere with the correct working of the physical laws. It is quite possible to estimate the ventilating power of a chimney if one knows the average temperature of the smoke in the flue and the temperature of the air outside. Let us assume that the height of a chimney from just above the opening of the grate to the top of the chimney-pot is 40 feet, and when the air outside is at 32° on a certain day the average temperature of the smoke in the chimney is 82° F. The ventilating power of the chimney depends upon the difference between the weight of a column of the air outside of the same height as the chimney and that of the smoke and air in the chimney itself. As the weight of the smoke cannot be estimated—*i.e.*, of the unconsumed coal—it will be assumed for the purpose of calculation that the atmosphere in the chimney is heated air. So 40 cubic feet of air at 32° F. weigh 3·23 lb. and 40 cubic feet of air at 82° F. = 2·94 lb. The difference is ·29 lb. or 4·64 ozs. per square foot. This pressure will give rise to a wind in the open air travelling at more than 10 feet per second. The velocity of the smoke in the chimney-flue as tested by a small and delicate anemometer appears to be between 5 and 6 feet per second: how is the difference accounted for? It is simply due to the friction, mentioned already, encountered by the air in getting into the room, and by the smoke in getting out of the chimney. What is the actual loss due to the friction, when ·075 lb. or $1\frac{1}{5}$ ozs. per square foot will give rise to the same velocity in the open air as is found in the smoke ascending the chimney? This pressure is rather more than one-fourth of the ventilating power of the chimney. It may be assumed, therefore, that after allowing for the extra weight and drag due to the smoke that

two-thirds of the ventilating power is used up in friction. It must be noted too that a velocity of $5\frac{1}{2}$ feet per second in the smoke column can only be obtained when reasonably good provision has been made in the shape of air inlets, and it is not an uncommon thing to find that three-fourths at least of the ventilating power of the chimney has been used up in friction. Just another calculation with this same chimney for spring temperature will show what the ventilating power is like then. Taking the outside temperature in spring at $52°$ and the average temperature of the smoke at $92°$—40 cubic feet at $52° = 3{\cdot}12$ lb., 40 cubic feet at $92° = 2{\cdot}89$ lb. The difference is $\cdot23$ lb. or $3{\cdot}68$ ozs. per square foot. Another chimney is 30 feet high, the spring temperature outside is $52°$ and the average temperature of the smoke is $92°$ as in the former case—30 feet at $52°$ F. $= 2{\cdot}34$ lb. and 30 cubic feet at $92° = 2{\cdot}17$ lb. The difference is $\cdot17$ lb. or $2{\cdot}72$ ozs.

The above calculations prove three points. 1. That the colder the air is outside the greater will be the difference in the weight between a column of air of the same height as the chimney and that of the smoke column in the chimney itself. In other words, the colder the air outside the greater will the draught be in the chimney. 2. The higher the chimney the greater will be the difference in density between the columns of air and smoke, and the greater the ventilating power.[1] 3. By increasing the heat of the smoke and air passing up the chimney the difference in density between the column of air outside and that of the smoke in the chimney will be increased and so add

[1] There is sometimes an apparent exception to rules one and two. If the chimney is in the outer wall fully exposed to the cold winds, and these are blowing strongly, the cooling effect of the wind upon the brickwork of the chimney may reduce the heat of the smoke column so greatly as to overcome the extra power furnished by a low temperature upon the air outside, or that due to an extra height of chimney. These exceptions only prove the rule, however, but they must be reckoned with. Such a state of things can be overcome generally by taking advantage of point No. 3 and sending a hotter column of smoke up the chimney.

to the ventilating pressure. This is the only reliable cure for cold chimneys in the outer wall.

The architect of a new house can increase the ventilating power of a chimney by inserting 12-inch pipes instead of a 9 × 9 inch flue, or make the brick flue 14 × 9 inches and thus reduce the friction, but this is not always advisable as will be shown in sequel. Again, the ventilating pressure of a chimney may be considerably increased by seeing that it is frequently and properly swept.

CHAPTER II.

VENTILATION OF DWELLINGS.

VENTILATION OF A HOUSE.—The remarks on this subject will be more general than particular, with a view to prevent repetition as much as possible. It will be best to deal with the kitchen first. Where this is in a separate wing with a passage between it and the hall, there is not much difficulty in keeping the smell of cooking from the rest of the house. In this case, if the passage has no room above it, a good-sized louvre ventilator at the top will allow any heated air which would get out of the kitchen to escape through. In designing new kitchens where expense is not much object, they are best made with no room above and so ventilated overhead that if air is drawn into it from the main building by the pull of the chimney, no heated air charged with the vapours of boiling fat and other odours will move back into the house itself. When cooking operations are in progress, a large number of chimneys will have sufficient draught to permit of a chimney-breast ventilator being worked near the ceiling, and if there was such provision the cooking smells would be vastly less potent. There is no doubt these odours are the greatest nuisance in ordinary villas and houses, and there is no doubt, too, that they give rise to most serious evils where delicate persons of small appetite breathe them, so that if such can be prevented from pervading the house and living-rooms generally much good will result. It will be worth while devoting some space to this consideration. Many a housewife knows to her sorrow that these smells are

deleterious and that they could be rendered much less pungent if the cook would only keep the kitchen *door shut*, but the cook will not do so, nor will the housemaid help in this direction. It may be worth while, therefore, to ask the question: "Why is it that the door leading to the hall is so persistently left open?" There are two reasons: 1. When the ovens are being used and great heat evolved by the range, a very large volume of air is drawn through the fire. If the back door is opened to supply this, the draughts are intolerable in cold weather, hence the air is drawn through the house in preference, because it is not so frigid. 2. If both doors are closed the kitchen gets so hot as to be unbearable. The cook, therefore, knows from experience that it is best to get the air from the house and accordingly *will* keep the door open. The occupier at this point may be inclined to ask a question. "Why is it that the smells come into the house even if the door is left open when so much air is required by the range, and so much has to come through the door?" The reason is that the air in the kitchen waiting, so to speak, to get into the fire of the range is greatly warmed and rises to the upper part of the room. More air can come through the doorway fróm the house than is required to feed the fire, so the heated air escapes through the top portion of the open door and finds its way back into the house to supply the place of a part of the cold air which has moved forward into the kitchen, and this warm air is laden with the smells of cooking.

The best remedy is to *keep the inner door shut* and make the cook open the window and the outer door *a little.* If the top window sash were opened 1½ inches and the bottom sash almost the same, much air would get to the range and the draught would not be greatly noticed. The *door leading to the back* should have a chain which allowed it to open 1½ inches, and the air coming in under the bottom sash and that from the door would not only supply the range but allow a little to drive out the heated air and smell of cooking through the

opening above the upper sash of the window. A good-sized Sheringham ventilator, 18 × 6 inches, Fig. 1, fixed near the ceiling in the outer wall and farthest away from the table where the work is done, ought to be provided in every kitchen. With such provision it is quite possible to prevent smells during the earlier progress of the cooking, but when the cook has to carry the results of her labours through the kitchen door towards the dining-room it is not easy to shut the kitchen door, and the living-rooms are soon pervaded by objectionable odours generally. To obviate this, if there is a passage leading from the kitchen to the other part of the house, a swing door of very light material should be placed between the kitchen door and the rest of the house, which can be opened by a gentle pressure and close behind one passing through with a tray. If the kitchen door opens into a hall on the ground floor, a curtain of light material with a lath of wood inserted in the bottom and not reaching low enough to drag on the ground will prove to be a very useful addition. A curtain of this kind reaching two-thirds down the doorway, having a thin wood lath at the bottom to stop the air blowing it through the kitchen door, will allow the cook to keep the door open and still prevent most of the smell being driven back into the house, because the cold air passes under the curtain whilst the latter does not allow the hot air and smells to leave the kitchen. This is an excellent arrangement. Should the kitchen be in the basement or sub-basement, and the stairs end in it, the difficulty of preventing the smells getting into the house above it is enhanced, because of the ceiling slanting upwards above the stairs. In such a case the door generally opens into the hall. The best plan then is to see that the door

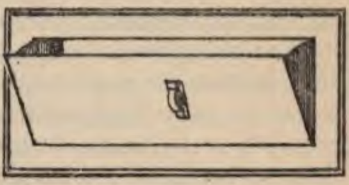

FIG. 1.—Sheringham Ventilator.

is covered on the outside by a hanging curtain, and that a cord is fixed at the top of the door in connection with the bottom of the curtain, so that when the door is opened the curtain is raised up one-third of the height. In this way it can be easily moved aside by one coming up, and the hot air and smell much prevented from ascending to the upstair rooms. If the door leading from the kitchen to the house is open and a curtain is hanging two-thirds down, the opening of the back door or the windows widely would cause heated air and smell to be driven into the house—*when these are open the middle door should be always shut.* The cook should be careful to shut the back door and not keep the windows much open when the food is about to be carried to the dining-room. If these provisions are made, and the details mentioned are attended to, the smells from cooking will be reduced to a minimum.

The ventilation of the cellars or the basement of a house rarely receives the care which it demands; hence the rooms there are usually damp and the air has a stale odour. If the kitchen is in the basement any rooms or stores adjoining can be easily ventilated by inserting a perforated brick near the floor of the kitchen with a way through to the place to be ventilated, and then allow some air to come from the outside into the upper part of the space which requires to be ventilated. Perforated zinc may be used to check the too rapid inflow of air, and larders in the basement can thus be easily ventilated. If there is a boiler in the basement which heats the water circulating through hot-water pipes, adjacent stores and rooms can be ventilated by its aid.

If there is no fire in the basement the matter is more difficult, unless there are fire-places provided. Where there are, the warmth given to the chimney-flues by other fires above ground will cause an upward current, and if adjoining rooms are connected to the one with the upward current by perforated bricks at the bottom of the floors, and the rooms have ventilators or perforated bricks near the ceiling leading to the outside

air, or to the window giving light, the basement will be much benefited. It is a very decided advantage to have each room connected at the bottom and at the top when the basement is not used to live in, because the wind produces suction near the ground and will often cause air to circulate from front to back and from side to side. In the winter, the temperature of the air in the basement will often be higher than it is outside, and fresh air will get in best then if it can find its way to the *bottom* of the basement, and the ventilators should be arranged so that the warmer air can escape at the top. In the summer the air is cooler in the basement than it is outside, and, where the basement is under the ground level all round the house, the air is very stagnant at this time of the year. The windows should be opened frequently, and every opportunity given for winds to cause movement of air. If the ground slants so that the bottom of the basement is level with the surface at any point, the rooms, stores or cellars should have one or two perforated bricks fixed in each parting wall near the floor level, and a hit-and-miss ventilator in the outer wall at the point where the ground outside is level with the floor of the basement, so that the cold air will flow out from store to store, and eventually through this ventilator in the outer wall. There should be ventilators at the top of the rooms which are below the ground level, so as to allow warm air to get in to take the place of the cold air which flows out. No fear need be entertained that more air than is necessary for ventilation will get in, nor that the basement will be rendered warm in consequence. In many cases, for want of this arrangement, basements are in a very bad condition in summer.

A word of caution is necessary to householders in reference to the air grids placed in outer walls for the purpose of ventilating underneath the floors. If only one grid is used to a room, the circulation of the air under the floor is very slight indeed, and two grids are desirable; but if a communication is left open under each floor from room to room, so that the air can

get from front to back or from side to side of the house, as the case may be, much better results will be obtained. A very good method of ventilating *small* rooms is to let a little air get through the skirting all round from under the floor, and strong draughts can be thus avoided. In severe winter weather the leakage of air into rooms through crevices between the boards of the floor is often sufficient to prevent the fire warming the room, the result being that the grids or ventilators on the outside of the house are closed up altogether. *Great care should be taken to remove these stoppers as soon as the frost is over*, otherwise the boards will become rotten, and miasmatic damp perhaps get into the rooms. Persons suffering from rheumatism, and indeed those who do not want to get it, living in low-lying districts, should be careful to ascertain that the floors are well ventilated underneath, and that the ventilators are kept *open*. This matter is much more important than it looks, and where houses have been built upon land which has been filled up with refuse material, unless the floors are ventilated and there is way from *front to back* underneath them, very serious injury to health may result.

The general ventilation of a ground floor will be next considered—the ventilation of a kitchen has already been referred to. The other rooms are usually self-contained, and if there are any ventilators they are generally fixed in the outer wall of the room itself. If fires only are used, and there is no hot-water apparatus installed, air may in some rare cases be taken from the hall, but it is wise to make each room draw its own air supply, independent of the rest of the house. The dining-room, if much used as a living-room, and if it is this which does duty for a smoking-room also, should have a sensitive chimney-breast ventilator near the ceiling, and a suitable grate for working it so as to prevent the fire smoking, especially if the flue is in the outer wall. The value of the chimney-breast ventilator cannot be too greatly magnified. Since the days when Dr. Arnott brought this prominently before the public it has be-

come somewhat discarded, see page 57, where this subject is dealt with more fully. It is impossible to ventilate any room thoroughly unless the air be drawn off near the ceiling. Some authorities state "that providing there is a velocity of 6 feet per second up the chimney, the room will have all the air it requires and will be well ventilated". After allowing for soot, a flue 9 × 9 inches would perhaps convey 3 cubic feet of air per second, 180 cubic feet per minute, and 10,800 cubic feet per hour, a very fair amount for an average family. But unfortunately three-fourths of this volume of air passes along the floor of the room if it is small, and gets to the fire without taking much part in the ventilation, and one-half, at least, ascends the chimney without being of the slightest benefit in removing the products which are due to breathing and to the burning of illuminants, if there are any. It is only necessary to place a delicate anemometer upon a floor between the door and the fire-place to find that the fresh air is sweeping along at a big pace, and does not greatly mix with or dilute the heated products above. As this is the case, it stands to reason that what is wanted is to stop much of the air going up the chimney just over the fire by means of a suitable grate, and cause the extra heat of the hotter smoke to aspirate and work an Arnott valve, Fig. 2, in the chimney-breast, when the heated breath, and vapour from the gas or other illuminant than the electric light, having ascended near to the ceiling by virtue of their lesser density, will be driven into the flue and expelled with the smoke. There are many chimney ventilators on the market, some having mica flaps or *papier maché* valves to shut against a down current, and to prevent the rapid closing of the door of the room bringing smoke backwards, but even mica flaps are not *nearly sensitive enough*, and a chimney ventilator should have its valve poised

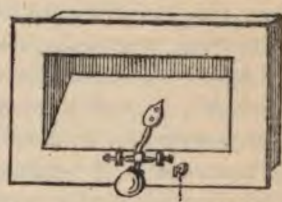

FIG. 2.—Improved Arnott Valve.

so that the slightest breath of air will move it. The author has frequently found well-made ventilators with mica flaps absolutely useless. If 10,000 cubic feet of fresh air come into a room per hour, and one-half of this is drawn off by ventilators in the chimney-breast, the occupants of the room will probably breathe air only *one-third* as contaminated as if the whole of this were allowed to ascend the chimney just above the fire.

Every dining-room should have a chimney-breast ventilator, then sufficient outlet ventilation will be provided. For inlet air much will depend upon the number of doors and windows in the room. If the window surface is small and there is only one door, a Sheringham valve, Fig. 1, p. 23, or a like arrangement should be fixed in the outer wall at the farthest point from the fire and within a foot from the ceiling. It is best to have these long and narrow rather than square. In a room 16 feet × 14 feet such a ventilator should be 14 × 4 inches over all. In a room 20 feet × 14 feet it might be 19 × 4 inches over all. In building new houses air inlets extending along cornices or behind picture rails are desirable. Where there is much window space, and two doors perhaps with not a little air finding its way through the skirting and between boards from underneath, no further air provision may be required, but the chimney-breast outlet should not be overlooked if this is the case.

The drawing-room should be similarly treated, unless the flue is in the outer wall and cold, when it may be as well to dispense with the chimney-breast ventilator unless a suitable grate is fixed for working it. If a window is so situated that it can be opened an inch at the top, all the inlet air necessary can be provided. In many houses a small third sitting-room is found. This is used as library and smoking-room or as morning-room. The size is generally under 13 feet square, and draughts from doors and windows are most pronounced in cold weather. If the chimney "draws" well the value of a chimney-breast ventilator cannot be overrated, but the grate should be

capable of regulating the amount of air which ascends the chimney so as to make the suction power of the flue remove much of the air from the top of the room. By this means the velocity of the air moving from the door and windows to the fire is so greatly reduced that there is no draught experienced—in fact, the velocity is reduced too low for a draught, and an otherwise most uncomfortable room is rendered habitable and pleasant.

Where there is a billiard-room on the ground floor, and it is built out so there is no room above, it is usually so cold that one fire is not enough in winter. If only a fire is used for heating, any side lights or glass ventilators at the top require to be made very perfect, and to this end felt may be used to make the spaces around as air-tight as possible. If there is a top light, the heat of the sun in summer necessitates that there shall be ventilators above, so that a current of air shall circulate from the windows in the side. Owing to the cooling effects of a glass turret or roof, and the great difficulty of stopping down-draughts when the fire is burning strongly, the cold currents falling upon the table in severe weather make one regret that top lights are fixed and that good, large, high side windows were not used instead. If there are high windows and these open at the top, ample ventilation can be obtained. Where hot-water heating is employed, top lights and ventilators can be used, and are certainly most desirable when the heating power is ample. Where a billiard-room is heated by coal, two fires should always be provided, and the necessary inlet air introduced.

Ascending to the first floor, it will be concluded that the rooms here are bed and dressing-rooms only. Very rarely one sees a chimney-breast ventilator in a bedroom, but it is of more value there than anywhere else perhaps, and every bedroom should have one. This ventilator should consist of a frame with a nicely fitting door which can be opened or shut by a chain coming to the mantel. There is neither mica nor any

valve in this arrangement, Fig. 3, and when the ventilator is open there is a clear way into the chimney-flue. This door or valve should be partly open whenever there is no fire burning, and it is far better to close the register and open this door wide than to have the register full open and no chimney ventilator. The vitiated air rises and is carried away from the top of the room, and for those who do not keep their bedroom windows much if at all open, the ventilator into the chimney near the ceiling maintains the air in the bedroom in a much better condition than if the foul air had to pass up the ordinary opening of the grate. These outlet ventilators must *not* have mica or any other valves, as there is not enough pressure on the outgoing air to work them. If a fire is lit, then partly close, or close them altogether if the draught is weak. If the house is heated by hot water throughout, all the grates should have closely fitting registers, and these should be always closed and the spent air carried off through one of these openings into the chimney—10 × 7 inches over all for a small room, and $13\frac{1}{2} \times 7$ inches for a large one. The door of the ventilator can be fully open when the temperature of the air outside is 45° or more, but had better be half closed at 35°, and generally closed altogether at anything below freezing point—the leakage through windows being so large in volume as well as through crevices in the register and around the door of the ventilator in the chimney-breast. The leakage through what appears to be a trifling crevice when air is below freezing point outside, and perhaps 55° or more inside, would make any one marvel who has had no previous experience in estimating it.

FIG. 3.—Chimney-Breast Ventilator.

If a bedroom is heated by an electric radiator, Fig. 25 or 26, pp. 159, 160, at present a costly luxury, the air so heated should not be wasted. It is in such a case as this that the chimney-breast ventilator is of exceptional value, and the register of the

grate should be rendered air-tight by placing a piece of thick felt or other woollen material between it and the grate. As before, the chimney-breast ventilator must not have any valves.

If the windows are situated so as not to send a current of air upon the faces of the sleepers, they may be opened a little or much as required at the top, and no other inlet ventilator is necessary. If the fire-place is in the outer wall and a window is placed on either side of the jamb, the window farthest away from the head of the bed can be opened. If the bed must be placed near the window, then a Sheringham or other ventilator ought to be fixed in the outer wall farthest away from the bed, and this should be kept open when required instead of the window. For summer ventilation the windows are available, and where the electric light is installed, small fans create an agreeable movement of air which can be directed away from the sleepers, or the fan can be fixed against the chimney-breast opening so as to drive the air into the flue.

The ventilators of bedrooms on the second and third floors should be much on the same principle as those on the first floor. Chimney-breast ventilators should be fixed in every case, and there must be no valve, only a door which will close practically air-tight if required. The upper rooms of a house have shorter chimneys than the lower ones, and as the ventilating power is generally proportional to the height, the draught is not sufficient to work a chimney-breast ventilator when a fire is lit, even if there is a free way into the flue, hence the door of the ventilator had better be closed when a fire is used. If, however, the grate is designed to work such a valve, it will be found that the ventilator can be partly open, except perhaps on very windy days. In a nursery, for instance, where there are a number of children, it is very advisable to work a chimney-breast ventilator in order to take off the vitiated air from the top of the room. Experience will soon teach the nurse whether the ventilator can be kept open or not, and it should be usually closed when much fresh coal is placed on the fire. Windows

kept partly open, and such-like admissions of fresh air, are not efficient substitutes for a chimney-breast ventilator, because with the latter the impure air is continually passing off from the top of the room. For inlet ventilation the windows are usually sufficient if opened one inch at the top, but where these are not available a separate ventilator in the outer wall should always be provided.

In the case of a nursery in a house about to be built the ventilation should be very carefully planned, and arrangements can be made at little cost for admitting fresh air which can only be done with much difficulty and expense in a room already constructed. Whilst the window or windows of a bedroom can generally form efficient air inlets if they are opened somewhat, it is a dangerous practice to rely upon them in a nursery. It is hardly necessary to point out how advisable it is to have a sunny aspect for the nursery, and, if possible, select a room with a good outlook, so that the children can be amused on wet days by looking through the window and their *eyesight practised in long distance vision*. The windows ought to be adapted for the children to look through without fear of colds or injury to the eyes from draughts. It is in winter such difficulties are encountered the moment the windows are opened, and provision should be made that the inlet air in winter is *not dependent upon the windows*. Indeed there should be such an abundant provision for fresh air apart from the windows that the children can stand close to them in winter without feeling draughts from air coming into the room around the sashes. To effect this most desirable end, air should be admitted through the cornice close to the ceiling and for a length of 10 or 15 feet or by some shelf arrangement such as that mentioned on page 68. Inlet air should come in freely, but it should be *largely subdivided* so that no draught is experienced in any part of the room.

The ventilation of attics and rooms under the roof is not an easy matter. In summer, where the electric light is used and the bedrooms are very hot at night, a small fan driving a

current of air from the foot of the bed towards the window will be found very agreeable. In the winter these rooms are usually cold, and there is generally not much need for inlet ventilators. It is almost impossible to prevent the heat of the sun causing the paper or plaster to crack, and let in air this way, whilst the windows can also be used as inlets. A chimney-breast ventilator fixed near the ceiling is again the best outlet possible for vitiated air.

The ventilation of w.c.'s requires some consideration. The old-fashioned design of making the w.c. as small as it was possible to construct it has not yet been duly remedied, and it seems by general consent among architects that the smallest possible space shall be devoted to this object. There never could be a greater mistake made. A person suffering from constipation gives rise to highly smelling products which have a peculiar property of sticking to and hanging upon apparel of all kinds. Such persons caged in a small box have their clothing saturated with germs and offensive odours, and the smaller the w.c. the more concentrated the effluvia. The w.c. need not be unduly large, but 6 × 8 feet is not unreasonable, although 5 × 7 feet would be a vast improvement on what is usually allowed. A long, narrow window (3 feet high at least) which opens outwards, just above the head of the person seated, answers best, and with this open, the foul atmosphere will be soon driven out. Where electricity is at command a small fan, Fig. 23, p. 155, fixed about 7 feet from the floor against an opening through the outer wall, which can be nicely closed up by a lever, is an excellent arrangement. On the right hand of the occupant a small handle is fixed against the wall. This handle opens the way through the wall and at the same time, if preferred, switches on the fan. The fan will soon aspirate air around the door (and window), and so prevent the impure atmosphere in the w.c. from getting back into the house. To make doubly sure that enough air gets in to feed the fan a ventilator should be fixed in the bottom frame of the door provided

with mica flaps which will not permit any air to pass from the w.c. to the living-rooms, but allow air from the house to get through to supply the fan. The fan arrangement can be operated by the seat of the w.c. in the same manner as the water supply is sometimes done, and this system certainly has the advantage that the ventilation is not dependent on the memory of the person using the w.c.

The ventilation of soil pipes and house drains requires most careful attention. It has been wisely decided that all drains conveying sewage matter should be laid in the open and not under a house if it can be possibly avoided. The joints of drain pipes can be cemented, but it is almost impossible to keep them air-tight, even if this is done carefully. Long iron pipes are best where the drains *must go under a house*, and then by preference under the hall or passage. The w.c.'s should have no wood casing, but be of pedestal form, and the pipe underneath should not pass through the floor, but at once lead through the outer wall into the down pipe. The down pipes laid on the old principle usually descend inside the house to the servants' w.c. in the basement and then into the drain. It is an extremely rare thing to find the joint between such a lead down pipe and the glazed pipes air-tight, and, partly on account of the dry character of the soil at that point, sewer gas percolates freely under the seat of the boxed up w.c. and thence into the house. By using only pedestal w.c.'s and carrying the outlet pipes immediately through the outer wall the chief danger is obviated, unless the drains pass under the floors of the house.

The ventilation of the soil pipes outside requires due precaution. The soil pipe should be continued to the top of the house, if possible, because it is not improbable that the gases from the drains will find an outlet thereby if the stipulations laid down by some Urban and other Authorities forbidding the use of a bend, trap or syphon between the w.c.'s and the main sewer are in force. If a house is so situated that the front is

upon a hillside, and the soil pipe ventilating shaft is carried up at the back of the house, it is not unlikely that the sewer gases will be drawn into the house and give rise to serious results. In many cases where the doctor cannot trace the cause of zymotic disease, sewer gas evolved from the ventilating pipe of drains is the consequence, and those who have noticed the peculiar and insidious movements of the gases and odours from a fire burning vegetable refuse in a neighbour's garden 30 feet above, will understand how sewer gas may be drawn by the suction of colder currents, and descend into the interior of houses which are themselves the objects of suction on the opposite side. As this is a serious subject it is advisable to give it some consideration. A high ventilating pipe can carry off much gas, and the mischief arising from the latter being drawn into a house in which *there is always a partial vacuum if a kitchen fire is burning*, cannot be too strongly pointed out. All those who have given attention to the subject regret the necessity that a bend or trap should be inserted immediately at the lower end of the soil pipe from the w.c.'s, but *such a bend or trap should most certainly be placed* in order to prevent sewer gas getting back into the soil pipe and up the ventilating pipe above. The ventilating pipe should be fixed only for the purpose of supplying readily the air aspirated by the water falling down the soil pipe and thus preventing any gases from the soil pipe finding their way into the pan of the w.c.

At the Public Health Congress held in London last July, Dr. Weaver, Medical Officer of Health for Southport, stated "that the question of sewer ventilation had been satisfactorily dealt with in Southport by using Webb's patent gas lamps which consumed only the sewer atmosphere for combustion. Since the adoption of these lamps the high temperature to which the air from the sewers is exposed has led to a very appreciable decrease in the number of typhoid cases." The sewer gases would be more effectively removed by the lamps in those cases where there were traps between the soil pipes

and the sewers, and the danger mentioned above would be overcome. If the posts carrying the lamps for street lighting are used simply as ventilating shafts they are unreliable, as when cold currents fall from the upper air the sewer gases are drawn into the flow which sweeps along near the surface of the road. When the road is situated in a hilly district, the sewer gases are drawn down more readily, and it is in such situations that good ventilating appliances are most required.

If the ventilating pipe communicates directly with the sewer, and if the stupid laws of the district will not allow interference with so dangerous a regulation, see that the end of the ventilating pipe is not fixed in such a situation, under the roof or otherwise, that the wind can exercise much pressure upon it, else it will not unfrequently happen during such winds that gulps of sewer gas will be forced back when emptying the pan of the w.c. *This is a real danger, and one which the author has practically demonstrated on several occasions.* In like manner if there is a trap below and the end of the pipe is carried right above the roof in a position where the upward suction of the flowing wind can exercise the greatest power, it not unfrequently happens that the air being drawn through the outlet causes the water in the pan forming the seal to be drawn forward in the syphon, and gradually pass over into the soil pipe until no water seal is left, so that the way from the pan of the w.c. to the soil pipe is open. *This is also a most serious peril.* When the ventilating pipe ends, therefore, well above the roof, either cover it with one of the pneumatic extractors on the market, if you want to throw money away, or else use a simple double bend like Fig. 4, because either will tend to prevent the wind extracting much from the end of the tube. But the tube must not be left unprotected with its mouth upwards, because the wind blowing over it gives rise to much suction—suction so

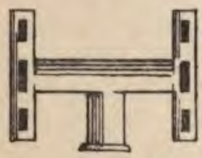

FIG. 4.—Top for Ventilating Pipe.

powerful that a sudden gust will depress the water by oscillation in the pan of a w.c. as much as two inches if the way to the sewer is blocked at any point. Those who use the w.c.'s in the house and notice that the water in the pan is moving backwards and forwards when all should be steady and at rest, may be sure this suction is due to one or two causes—either the wind blowing down the mouth of the ventilating pipe of the soil pipe causes increased pressure, because the former is under the roof, or else there is too much suction caused by the aspiration of the wind blowing across the open end of the tube. It is possible in some rare instances where the ventilating tube has been choked by a bird's nest that the wind pressure in the main drains may give rise to this movement of the water forming the seal, but whatever the cause, if the occupier cannot trace it, let him at once see that the matter is attended to and set right, because most serious evils may result from neglecting these ominous indications that something is wrong.

CHAPTER III.

INFLUENCE OF WINDS UPON DWELLING-HOUSES.

THE benefit due to the moving of currents of air or of winds in towns cannot be overestimated, and it is not easy to picture the conditions which would prevail in a large town built upon level ground if there were no winds or air currents travelling over it. The velocity of the air currents increases greatly at an altitude above the housetops and other impediments to its progress, so that at about 1,000 feet above the surface the wind, which travels five miles an hour near the ground, moves at a velocity of about ten miles an hour. It is this greater velocity of the currents in the upper air which tends so much to move the air in the more crowded parts of a town, and the open spaces which here and there dot our centres of population help very materially to draw the air from the more congested districts. Those who live in wide streets cannot fail to notice how the smoke from the houses is frequently drawn down perhaps 20 feet towards the ground level, and especially is this the case if there is an open space of some area close by. As this is a point of much interest, it will be best perhaps to consider an example. Those familiar with the City and the Bank of England will have noticed that the Bank buildings are low, and much lower than those on either side. At this part, too, there are several roads which converge by the Mansion House and the Bank where the area of open and low buildings is considerable. When the wind blows across this area it meets with far less friction than it does over Queen Victoria or Thread-

needle Street, the consequence being that the velocity of the wind is much increased as it passes over the Bank Buildings, etc., and the increased suction which results has to be satisfied by air drawn from some of the streets near, so that if the wind blows from the south or south-west Queen Victoria Street at the Mansion House end supplies a very large volume, as do Threadneedle and Lombard Streets also. Under these circumstances the courts and alleys where they exist in the immediate neighbourhood of an open space or four cross-roads are likewise drawn upon, and this action of the winds upon open spaces is an infinite benefit to ventilation. The friction resulting from wind blowing over housetops, etc., is very great,

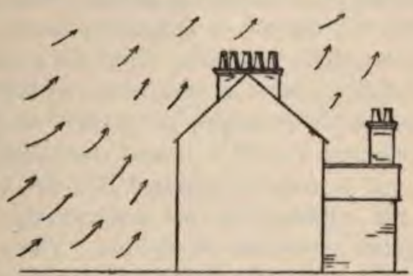

FIG. 5.—Upward Movement of Air from an Open Space.

so that the moment the air moves over a square, a park, cross-roads or any open space, the velocity increases at a bound, whilst an upward twist like that shown in Fig. 5 is given to the air in the open space. The result is that immense volumes of air are twisted and lifted from the open space near the ground into the currents moving above the housetops, and the air from the streets and alleys in the immediate neighbourhood flows into the open space to supply the place of that which has been aspirated and lifted above the housetops. It is this strange and apparently erratic action of the wind which gives rise to so many smoky chimneys, and in the residential portion of a town those who have followed these remarks will have no diffi-

culty in seeing the effects produced if they note the strange forms of the chimney-pots upon the houses adjoining such open spaces as have been mentioned. The full benefit of the suction power of the wind moving above the housetops can scarcely be explained in detail, and only the main considerations will be pointed out. Wind blowing over housetops and at right angles to the streets exercises suction as it travels over them, and when it leaves the highest point of a house and crosses a street, the velocity at once increases, with the result that air is aspirated from the street, from the garden, if there is one, and from all open spaces, and even the air in the houses is more or less influenced by the flowing winds. If the angle the street presents to the wind is greater or less than a right angle, the wind will aspirate in proportion to the size of the open spaces over which it travels. When the wind passes over the tops of buildings, some of which are very high and others differing considerably in height, the suction or aspiration is much more effective than if it passed over buildings of the same height, but it must be admitted that the action of the wind upon the chimney-tops not unfrequently nullifies the benefit of greater movement in the air. Those who travel upon high-level railways in London and elsewhere will notice that the cowls and metal tubes so numerous in the City are rarely to be seen upon houses which have their roofs on or about the same level, and where a large district of this kind occurs, the wind effects are not turbulent except upon cross-roads and open spaces. If a house is situated upon the end of the ground at A, Fig. 6, where one street branches off into two, and the prevailing wind blows in the direction of the arrows, the aspiration of the wind upon A will be immense. The suction upon the windows and upon the tops of the chimneys will be great and erratic, so that the ventilation of the rooms will be difficult. Furthermore, the dust driven and sucked forward by the wind will be very trying. These points are worth considering by any would-be tenant of a house so situated.

When the wind blows over houses which lie upon the side of a hill, and at right angles to the roadways, the effects are not very marked, except upon the chimneys of the upper floors which may give trouble by smoking. Houses situated on the crest of a hill are subject to the action of most winds, and if the prevailing winds blow at right angles to the longitudinal crest of the hill the aspirating effects are often violent, and it is always best in building houses so situated to provide for this difficulty by fixing grates which can be made to send hot smoke up the chimney and produce strong ventilating power. Winds blowing over such a hill-top exercise much suction upon the back premises of houses, and chimney-pots which neutralise wind suction and good grates should be used. If the chimneys are in the outer wall all the more reason exists why the grates and chimney-tops mentioned should be fixed.

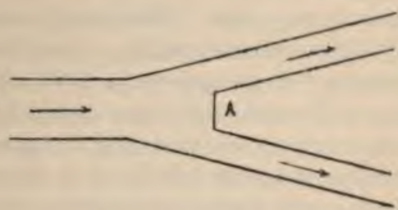

FIG. 6.—Y Branch Roads.

If the wind blows over ground gently slanting in the same direction the effects are not violent nor upsetting to ventilation. The popular idea is, however, the opposite to this, *viz.*, that the wind blows down depressed areas, down chimneys, down ventilators, etc. The first action of a wind travelling over a house situated in a small basin or depression is one of appreciable suction, both at the ground level and at the top of the house. Not much air gets into the rooms through the doors and windows, and extra smoke and air are sucked out of the chimney-tops. The air in the rooms having fires is so much rarefied by this process that the instant there is a lull in the

blowing of the wind the expanded air snaps back and down the chimney to supply the place of the air previously sucked out by the flowing wind. It will be noted that a square, a street or a garden walled in by houses is but a chimney of larger area, and the effects are not dissimilar, only there is this difference, the streets and courts which lead to the square or open place are not so confined as a room in a house and supply all the air the square requires without much friction resulting, so that when a gust of wind supervenes, the air in the open space does not snap back, but only waits for another blow of the wind to soar upwards as before. This upward suction and reduction in pressure is the general action of the wind as it travels over *all open spaces,* but the results differ somewhat, according to whether the wind is leaving the tops of houses or whether it is encountering them after moving over open ground. The effects in the former case have been sufficiently explained already. In the latter, if the air has moved for some distance over the ground level, it will strike a house in front with much force. The author has been consulted with regard to houses in most difficult situations, and one in particular was so powerfully influenced by the wind that the smoke and sparks from a fire were actually forced across a room and some distance in the direction of the staircase. No one acquainted with such situations would believe it possible that the wind could so upset the chimneys of a house and destroy the ventilating power. The first effect of the wind striking an exposed house front is to form a vertical layer of air from one to six feet in thickness, according to the velocity of the wind.[1] This layer of air acts like a cushion or buffer which expands or contracts according to the varying pressure of the wind, and its action is not unlike that of a jet of water made to impinge at right angles against a flat and vertical surface. The water not only flattens out and forms a cushion, but the ring increases in width

[1] The author carried out a series of experiments against a cliff at Broadstairs, the results of which were briefly communicated to the meeting of the British Association at Bradford in 1900.

according to the pressure of the water. Wind blowing against a vertical surface not only forms a cushion or buffer, but flows upward over the upper edge of the cliff or the vertical wall of a house. The consequence is that the air of the upper currents flowing above the cliff or housetop being one continuous elastic substance and mass with the air flattened out against the front of the house draws it upward quickly at its outer edge, and it was found that this upward movement was so potent that one could hold a silk thread 2 feet above the top of the cliff and near its outer edge when a moderate wind was blowing without any movement of the silk thread resulting. This protected area, brought about by the upward twist of the air currents upon the air in the depression beneath the front of the cliff, extended for 10 or 20 feet at certain heights above the top of the cliff from the edge upwards. The upward suction at these points was considerable, giving rise to small whirlwinds caused by the air from the land flowing forward to feed the upward suction caused by the upper currents. The results of these experiments showed that the chimney-tops upon houses in a square upon which the wind impinged would be protected greatly by the air sucked upward as it struck the house fronts, and, instead of the wind as usual flowing over the chimney-top and encountering much friction, the ascending air twisted up would aspirate powerfully without friction, hence much air and smoke would be drawn out of every chimney so situated. This accounts for the great difficulty there is in keeping fires from smoking in rooms upon upper floors, especially in houses so situated.

The cushion or buffer formed by wind blowing against a vertical surface explains the action of the wind upon chimneys close to and under the tops of walls against which the winds blow. A house may be situated in a street and the owner rebuild it, raising the walls 10 feet or more above those of the houses on either side. The chimneys of one or both of the lower houses may rest against the pine ends of the new structure,

and 10 feet of perpendicular wall exist between the tops of the flues and the atmosphere above. When the wind blows at right angles to either pine end, a thick cushion is formed, and the pressure upon the air forming this cushion or buffer may be much greater than that upon the smoke in the flue or upon the air in the rooms at the street level. If this extra pressure at the mouth of the chimney is as great as or greater than the ventilating power of the chimney, the air will be forced downwards and the chimney will smoke. This occurs often in such situations. A flue drawing well emits a current of smoke travelling 6 feet per second. This velocity is only a trifle more than four miles per hour, so that a wind moving at eight or ten miles per hour, which is only a strong breeze, blowing dead on the face of the wall will easily prevent the smoke from issuing. If a high velocity pot will not stop the down-blow the flue must be carried up level with the top of the wall, or the other pots, as nothing else will be satisfactory.

Those who act wisely in the selection of a town house will give some thought to the probable action of the wind upon it. No greater misfortune can happen to the tenant than to find after he has nicely decorated and furnished his house the position thereof is such that every movement of air brings a swirl of dust which circulates in the form of a small whirlpool against the front door, and sends a shower into the front room if the windows are open. If the wind blows over a crescent it sucks air out of the more open part and from any street or passage leading into it as from C, Fig. 7, and during every lull the air coming from C to supply the place of that moved upward has a merry waltz at B, forming a miniature whirlwind, swirling and gamboling repeatedly. Wherever the wind causes air to move in a circular direction, as at street corners and other positions, swirls of dust will be the result, to which may be added suction of the wind upon the doors and windows near the ground level, preventing sufficient air from entering to properly supply the fires, which smoke accordingly.

This wind suction is one of the most troublesome things to overcome. On one occasion a number of offices were inspected which usually were free from smoke trouble, but when the wind blew in a certain direction the nuisance always occurred. The wind on these occasions blew down the street upon which the windows of these offices looked. The windows were large, and the wind suction upon them was such that the air which usually got in to feed the chimneys was greatly reduced in amount, and as there were two or three fires in rooms associated and open to each other, the weakest chimney smoked. This state of things was remedied by introducing air from the other side, but such a cure is not often possible, and when this wind

FIG. 7.—Air Movements in a Crescent.

suction near the floor level occurs upon a house on the top of a hill or in a very exposed situation it gives rise to much trouble, especially where there are chimneys in outside walls. Wind suction either at a high or at a low level in streets has never received the attention it deserves, and it is probable there are few who realise what it means.

When the wind blows over a chimney-pot the smoke is drawn out at a quicker rate. This is due to the elasticity of the air and its being an elastic solid. The wind must travel at a greater rate than the smoke issues naturally from the flue before it aspirates at the top of the chimney, but as an ordinary breeze will accomplish this, winds exercise much suction or aspirate considerably from chimney-pots. If the opening was

not at the top of the chimney but on one side of the pot as in Fig. 8, would the wind aspirate from that orifice? Certainly, when it blew in the direction of either arrow. The crevices around the windows of a room through which the fire gets its largest supply of air are subject to just the same suction as the end of the flue in Fig. 8. When the wind blows in a line parallel to the front of the house, the air outside the windows in that front will be strongly aspirated, and much less will get in to feed the fires. This trouble is encountered chiefly with houses situated upon cross-roads, and detached villas and houses upon hilly situations. A good grate and inlet air supply from another quarter, if possible, are the best remedies. Where the wind suction is frequent and considerable by reason of the windows being in a line with the prevailing winds, a little window or ventilator which can be opened outwards so that the winds blow *into* it will neutralise the suction. Wind suction upon openings into houses near the ground level and wind aspiration outside windows generally occur when the weather is temperate, so that a ventilator may be opened without much discomfort.

FIG. 8.—Side Opening in a Pot.

The suction exerted by the upward twist already mentioned as occurring when the wind impinges against the face of a cliff or of houses on the farthest side of a square or open area is not confined to the chimney-tops or ventilators on the roofs of houses or public buildings. The writer prefers seaside resorts which have bold natural beauties, and so usually visits those places situated on high cliffs. From a careful study of the wind's action upon the front of the cliff or terrace and the subsequent effects upon the chimneys of the houses, the reason of one of the unpleasant experiences often observed when the wind blew stiffly became evident. It was found that the houses on the front facing the sea were generally connected to the main drain which ran along the promenade and eventually joined the outfall sewer which was led some distance

into the sea. No matter what the state of the tide, the smell from the drains could be observed when the wind blew towards, or at right angles to, the high sea front, and in many towns several of the manholes and air-shafts had to be closed carefully as the smell was so intolerable. This emission of gas from the drains was attributed to the wind pressing against the mouth of the outfall sewer and the gases being forced inland in consequence. The writer was never satisfied with the explanation because the outfall sewer is rarely exposed at any seaside resort even at ordinary low tide. After noting the upward twist and suction caused by the wind impinging against the front of a cliff the reason for the offensive exhalations from the drains was explained—*the gases were sucked out of the drains instead of being forced out by the wind.*

The sanitary authorities at seaside towns situated as described do not fully realise the grave dangers which may result in consequence of this suction of gases from sewer ventilators and the swirl which results from the wind's action near the ground level. For instance, let us suppose a gust of wind is blowing against the cliff, the suction upon the drains along the front or for 100 yards inland perhaps is considerable. The next moment the gust ceases, and as there is a partial vacuum formed over the area mentioned, the air is instantly drawn back—the consequence being that the gases from the drains which had been drawn upward descend and flow along the road and into the houses. Not long since the author experienced the offensive exhalations mentioned in a very pronounced fashion at a promising seaside town. Unfortunately many of the lodging-houses are old, so that the soil pipes are fixed inside and the danger of the suction effects is increased. It is a pity visitors to the seaside do not refuse to take apartments where modern sanitary appliances have not been adopted. In these old houses when there is reduced pressure caused by the upward twist of the wind, the air in the space above where the soil pipe joins the house drains and between each w.c. is sucked out, the

result being that where the joints leak, and they frequently do leak, there is an emission of soil and sewer gas and the smell gets all over the house. Where there is a gas cooker this smell is attributed to the "gas," but in very many instances it is due to *sewer* gas. If visitors to the seaside would not take apartments in such houses matters would soon be altered, but they find so much difficulty in obtaining accommodation at all in August that they have to put up oftentimes with what they can get. The sanitary authorities, therefore, of every health resort should be empowered to compel those who let apartments and keep lodging-houses to fix the soil pipes outside, and adopt pedestal w.c.'s of approved construction. If this precaution is neglected the public will flock to newly built towns and the older places with much more natural beauties will be neglected. The writer has wondered frequently how so much benefit is obtained under the circumstances from a visit to the seaside, but it is generally agreed that that benefit is proportional to the number of hours the visitors spend out of doors.

Sewers in streets immediately below the crests of hills over which the wind is blowing are likewise exposed to the suction mentioned. The action of winds upon undulating and hilly districts is a subject which ought to receive immediate study by the sanitary authorities of every town inland as well as at the seaside now that the suction power of the wind has been elucidated and shown to be as potent as the better known effects of increased pressure.

CHAPTER IV.

AIR, AIR INLETS AND OUTLETS.

THE author does not aim to make this chapter a complete exposition of the physical composition of the atmosphere, nor a scientific guide to the estimation and determination of the proportion of the various constituents present. Such information can be obtained in any treatise on physics or chemico-physics, with which, it is needless to say, the student of ventilation should make himself familiar if he wants to master the subject. Nor will much space be devoted to the discussion of theoretical and impossible volumes of air which may be necessary to keep down the proportion of carbonic acid or anhydride within given limits. The practical common-sense view of doing the best with the homes we live in will be adopted.

The air makes its way into our houses as nearly as possible in the condition which nature affords it, only more or less contaminated in towns by the processes of manufacture, by dust, by unsanitary drains, etc., and in the country by decomposing manure and vegetation, filthy yards and outbuildings. This contamination, as a rule, is not very serious. Four parts of carbonic acid in 10,000 of air with traces of other gases, some particles of soot and dust, organic matters and organisms, and the sum of the impurities is nearly complete. The aqueous vapour in the atmosphere is often included with the impurities, but this is wrong, and its presence is salutary as well as necessary. The quantity of aqueous vapour present depends upon the temperature of the air, the state of the vegetation, and

whether there is little or much water in the immediate neighbourhood. About one per cent., perhaps, is the average present in the air of this country, but it varies from traces after some days of severe frost with easterly winds to saturation during continued misty weather with gradually lowering temperature; although this latter condition is very rarely attained. The presence of a small or large proportion of aqueous vapour in the atmosphere outside our dwelling-houses does not much influence those who live within, especially if the rooms are heated by fires, whilst the author's experience of air warmed by radiators at 150° F. without fires points to the same conclusion. There is no reason why the tenant of a house heated by hot water and without fires in the living-rooms should not make his radiators evaporate water and increase the humidity of the warmed air, but this is not necessary unless he is suffering from a nervous ailment which causes him to fancy the air is too dry, or from a chest affection which requires that the air shall be moist. It may be concluded that as the burning of gas for illuminating purposes gives rise to much moisture, the air in rooms heated by hot water or even by fires will be uncomfortably dry should the electric light be substituted for gas, but such is not the case, and the presence and breath of two or more persons in a room soon augments the proportion of aqueous vapour. In very dry and cold weather, however, the tobacco smoke in rooms which are so greatly benefited by the drier air when the atmosphere outside is mild and damp, is somewhat acrid, like the air in the "Twopenny Tube" after it has been much heated; but if many persons are present in the room the breath neutralises this acridity. It not unfrequently happens in the low lands, and often upon the mountain side also, that the atmosphere is full of mist or damp fog, and in the act of walking, even under an umbrella, the clothes become covered with dew. This deposit of moisture is not the result of supersaturation of the air with aqueous vapour, and to a subsequent condensation in consequence of a lowering tem-

perature, but is due to the moisture condensing from above in very fine mist, instead of the minute particles of water being aggregated in the form of raindrops.

It will not be of much benefit to inquire whether this is the result of electrical action or not, but when such fine mist is present in air, it renders it sluggish in movement and nearly stagnates natural ventilation of all kinds. This misty condition of the atmosphere is found in cities and towns chiefly, but not always, during mild weather, and when it prevails the tenant of a house will be wise if he opens a window of the living-room a little at the top so as to allow more air to come in, otherwise the room will become unbearably close and burdensome. If this is not done, the air in the room gets greatly and quickly heated, the temperature rising rapidly to 70° or even 80° F., because moist air is a good conductor, with the result that the germs present from the breath and in the floating dust thrive and multiply with incredible rapidity. From observation and experiment, the author concludes that not more than one-half of the usual volume of the air laden with mist gets into a room through the chinks between the window sashes and their frames or those around doors, whilst if this state of things continues for a time, the dew or moisture becomes condensed into a liquid which not unfrequently so fills up some of the chinks as to prevent any air passing through. The tenant will do well if he realises fully how inimical to good ventilation the presence of mist in air is, and that when the atmosphere is in this condition it is very necessary that a ventilator or window should be opened. When only one or two persons are present in a large room, it may be wise to exclude the damp air, but if there are several people in a small room, the condition of the atmosphere will soon be one of saturation and dangerous to health, because toxic compounds may be formed under such circumstances.

It has been stated that the air gains access into our homes, and especially into our living-rooms, much in the condition in

which it is afforded naturally, and, excepting such weather as just described, the soot and dust particles find their way in somewhat rapidly. If the air is admitted through a ventilator covered with perforated zinc, very little air will get in unless the holes are large enough to let the smuts pass. If it is desired to intercept the smuts, the open canvas called scrim used by paper-hangers will be found useful for the purpose. A strip of this material can be fixed to the frame above the window sash and also to the sash itself, so as to allow the latter to be lowered an inch or two, whilst a little of the same material can be used to cover the open space between the two sashes. The author is of opinion that for an ordinary living-room it is not wise to do more than stop the large smuts, if these occur in great numbers as is the case in Hampstead, and other side-land and hilly districts, which receive soot wafted by the prevailing winds and breezes from miles of low-lying houses. These sooty particles are highly antiseptic and contain, besides tarry matters, ammonia and ammoniacal compounds, and it is extremely probable that their presence has not a little to do with the satisfactory condition of the health of London. Air finds its way into houses generally through the crevices around the sashes of the windows and through the chinks around the doors, and a system of washing and filtering the air before it gets in is very rarely attempted. The author is confident that the presence of more moisture due to washing, the removal or alteration of electrostatic conditions (see Appendix, No. 1), the presence of the germs and deleterious gas and matter not removed in the process, whilst the antiseptic soot has been separated, render the air enervating, and those who inhale it become limp, so that the washing and filtering do more harm than good. Where large volumes are moved and required as in the House of Commons, the adoption of a scrim screen is useful and necessary to prevent the aggregation of much soot and dust.

With regard to the quantity of air which one person present in a living-room requires per hour, the question resolves itself

into this—how much can he get? Dr. Parkes has stated that 3,000 cubic feet are required per head per hour. If so, it is to be feared that something more than a fire is necessary to bring it in. It will be well to inquire into this matter a little more fully and in some detail, as it so closely bears upon the well-being of the community generally. For the purpose of illustration a living-room of the size used by the lower-middle and upper-middle classes, *viz.*, 16 by 15 feet, will be taken. This room is 10 feet high, and there are 2,400 cubic feet of air in it. The chimney-flue is 9 inches square and there is a good draught, the smoke in the chimney showing a velocity of 6 feet per second. The air and smoke passing up the chimney amount to 12,150 cubic feet per hour, so according to Dr. Parkes, sufficient for four persons. During moist or mild weather, the velocity is reduced to 3 feet per second, and if the chimney has much soot in it, that velocity, however, falls under such conditions to 2 feet or less per second. When the velocity is 2 feet per second the air getting into the room is only 4,050 cubic feet, or a little more than enough for one person. This is bad enough if there are six or more persons present, as the total quantity of air getting in affords less than 700 cubic feet per head, but from repeated experiments the author has found that this volume is greatly overestimated, and that from 150 to 300 cubic feet would be much nearer under the circumstances. It has been stated by some authorities that the air in a room becomes quickly mixed, and that the proportion of carbonic acid is much the same throughout. Others have denied this, showing that the proportion of moisture and of carbonic acid is largest near the ceiling, although admitting there is a very appreciable quantity at the level of the top of the grate. Now let us examine what is going on. The fire is burning brightly and the velocity in the chimney is 6 feet per second. Three gas jets are alight. A delicate anemometer placed on the floor within 3 feet of the bottom of the door turns rapidly, and if close to the door it is violently affected. If one goes to

the window and lowers the hand from the sash down to the floor, and the air outside is cold, it is found that the air near the floor level is cold also. If a thermometer is placed on the floor between the window and the grate, the difference in temperature is appreciable, whilst if it is placed in a line between the door and the grate, the same result is found, only in a more pronounced fashion. What is the meaning of this? Simply that much the largest quantity of the air that gets into the room under and around the door finds its way to the fireplace and up the chimney without diluting and refreshing the air in the room, and that much of the air getting through the crevices around window sashes does the same thing. If it is stated that in many rooms three-fourths of the air supplied by the grate passes up the chimney without mixing with the vitiated air above, proof of this may be demanded without its being forthcoming, because the matter is so difficult to be determined with accuracy. Again, if an anemometer is held just level with the top of the fire-grate it may be found that there is no draught or movement in the direction of the chimney-flue. On the contrary, there is a slight movement upward unless the temperature outside is very low, but so slight in some instances that the finest shred of silk is necessary to indicate it; and when the draught in the flue was great the author has known an almost quiescent condition of the air at the point in question. Why is this? If air is an elastic solid the pull up the chimney ought to cause a downward current towards the flue from at least 6 inches above the top of the grate. The reason is that the radiant heat direct from the fire, and the radiant and convective heat afforded to the air passing over the fender, irons, etc., causes much of the air near the floor to ascend, but the velocity of the current moving up the chimney almost entirely neutralises this upward movement, with the result that the greater part of the air so warmed passes up the chimney. This action of the air as it sweeps into the flue is very much against the best ventilation of the room. If the velocity of the air going

into the chimney through the grate was only 3 feet per second a large proportion of what came into the room would be warmed by the radiant heat and the hot fender, irons, etc., and rise towards the ceiling, displacing by downward pressure equal volumes of vitiated air, so that only one-fourth of the air getting into the room passed away without diluting the vitiated atmosphere. It may be argued, however, that only one-half of the air got into the room when the velocity was 3 feet instead of 6 feet per second. This is perfectly true, but it may not be out of place, however, to note here how the foregoing conclusions explain why it is that a small fire in the autumn or in the late spring heats a room so greatly, and that it is due to the air warmed by the radiant and convective heat from the fire, fender, irons, etc., passing up into the room in front of the mantel, instead of both air and heat escaping by the chimney.

If the velocity of the smoke in the flue is 6 feet per second or more, it is no uncommon thing to find such vast volumes passing direct to and up the chimney in small rooms that, without desire to exaggerate, one must conclude that often *three-fourths of what comes in takes practically no part in reducing the proportion of the impurities*. These figures mean that if the flue velocity is not more than 4 feet per second, only 8,000 cubic feet per hour get into the room, whilst from 3,000 to 4,000 cubic feet of this volume ascend the chimney without scarcely, if at all, mixing with the air above. Again, when the velocity in the flue is 6 feet per second, 12,000 cubic feet of air come in altogether, and 6,000 cubic feet in large rooms and in very small rooms even 8,000 cubic feet or more of this quantity take no part in reducing the pollution of the atmosphere above. It may be remarked that the greater the velocity of the smoke in the flue the larger is the volume of air furnished to reduce the impurities above the grate level notwithstanding. This is true, generally, though not always in very small rooms, and is the result of two forces: (1) The air sweeping so swiftly over the fire keeps it clear and bright in front, so that the radiant

heat penetrates far into the room, warming the air and causing it to rise upward outside the limit of high velocity such as that immediately in front of the grate; (2) The air moving to the fire at a greater velocity aspirates and draws into the travelling current more air from above. In the case of a chimney in which the velocity of the smoke was 3 feet per second, the air escaping without doing much work is 2,500 cubic feet per hour, perhaps, whilst in the case of the chimney in which the velocity of the smoke is 6 feet per second, it is 7,000 cubic feet per hour possibly. At this point a most important question arises: "Can this waste of air (and heat) passing up the chimney be made to dilute the atmosphere which occurs at and above the level where the occupants breathe, *i.e.*, a foot or more above the level of the opening of the grate?" There is no question connected with the ventilation of dwellings so weighty as this. The answer is, that much of this air may be used, and with infinitely greater comfort to the occupants. In the winter when the temperature outside is very low, the volume of air getting into the living-room is large. That which finds its way in around the window sashes is very frigid, and what makes its way under or around the door is little warmer, because it comes down from the bedrooms into the hall which in the majority of instances is not warmed. The consequence is that the air as it passes the feet of a person sitting near the fire gives rise to intolerable draughts, which are frequently so cold during severe weather that the occupants complain of being "roasted" in front and "frozen" behind. To prevent these draughts at the floor level, and the unnecessary loss of radiant and convective heat from the fire, fender, irons, etc., the first thing to do is to check or reduce the volume of air going up the chimney from the grate. If the grate is one with a movable canopy which acts partly as a damper and closes up the flue somewhat when it is pressed back, it will answer the purpose required, provided there is a good draught in the flue, and this flue is in an inner wall. When the fire is clear and burning brightly and

hot, the canopy can be closed home in severe weather without apparently much reducing the volume of air going up the chimney. The reader may be inclined to think that this statement should be taken *cum grano salis,* but this is not the case for the reason already given, *viz.*, that the moment the air passing over a good fire into a chimney is reduced in volume, the smoke becomes hotter and gives rise to a much higher ventilating power, which in turn forces the smoke through the narrow space or opening at the back and sides of the canopy at a high velocity. According to this explanation the reduction of the volume of air and of the draughts will not be great, but the friction which the air encounters in passing through the narrow opening allowed by the closed canopy, affords the means of utilising much of the air for ventilating purposes which now escapes without taking any part in the reduction of the impurities present.

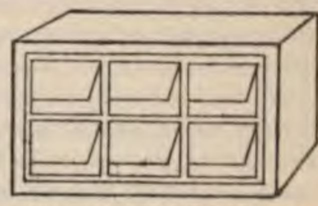

FIG. 9.—Mica Valve Ventilator.

If there is an Arnott valve in the chimney-breast, or one of the improved flue ventilators on the market, *when the air outside is very cold* and that which ascends the chimney is checked as described, the chimney-breast ventilators mentioned will act more or less effectively, with the result that a large portion of the air which previously ascended the chimney through the opening into the flue above the grate may be made to pass through the chimney-breast ventilators fixed near the ceiling of the room. If this is done, the velocity of the air moving from the windows and door at the floor level will be greatly reduced, and of course the draughts likewise. The reader may ask: "Why is it the chimney-breast ventilator with light mica, Fig. 9, or *papier maché* valves is only said to give good results when the air outside is very cold?" The reason is that so much air pressure is required to lift or open these valves that all the air

passes up the chimney by the grate in preference during mild weather. This is very unfortunate, because it is during the spring and autumn that there is the greatest necessity for more ventilation, whilst during cold and severe weather the value of more air above the level of the grate is not so apparent. This matter has been mentioned in chapter ii., but as it is of such vital import it is dealt with in detail here. The question which will be asked at this point is, "Cannot the difficulty of the chimney valves be overcome?" Yes, in two ways—either by using a valve[1] or valves so delicately poised that the air will move them without much expenditure of pressure, Fig. 2, or by doing away with valves altogether and using a chimney-breast ventilator with a door which can be opened at will to the extent desired, and closed perfectly when necessary, Fig. 3. In the former case the ventilator must be thoroughly good and reliable, very delicate, and well finished. This ventilator should not only have a delicately suspended valve, but the valve should be so controlled by mechanism that it can be shut altogether, opened fully and kept in this position, or allowed to play back and fore according to the variable pressures in the room.

The advantage of having a valve or valves is appreciable, because the smoke is liable to be drawn out every time the

[1] The valve or chimney-breast ventilator invented by Dr. Arnott was a very sensitive instrument. The valve was suspended much in the same manner as a delicate scale. He knew how trifling was the air pressure available in autumn and spring to work the instrument, hence the importance of having it sensitive as already pointed out. Since the above was written the author has examined his original writings and drawings, and it transpires that Dr. Arnott finding some manufacturers in their endeavour to cheapen and simplify the ventilator turned out less sensitive instruments, pointed out how inefficient they would be. Since then balanced valves requiring more pressure to move them than is to be found in an ordinary chimney-flue have been placed on the market, and the value of the real Arnott ventilators has been misrepresented. Fig. 2 is the original Arnott valve, only the bearings figured here are needle points and the valve plate is to consist of much lighter material.

door of the room is closed *rapidly*, and the chimney may be inclined to send out a puff of smoke at the grate level when the door is similarly *banged*. If the housewife only knew that the rapid closing of a door interfered both with the smoke going up the chimney by the grate and also the air through the chimney-breast ventilator, more care would soon be taken with the opening and closing of the doors of living-rooms. If this was so, a chimney-breast ventilator *without a valve* could be used with great effect, and much comfort experienced by the inmates of the room. If the flue ventilator is 9×6 inches in the clear and there is no valve, the proportion of air passing through the ventilator into the flue will be such that no draughts will be felt by those sitting near the fender. The tenant provided with such a chimney-breast ventilator having a front which closed perfectly when required, can regulate this front and leave it one-fourth, one-half or full open as practice has shown best. There are some chimneys that will not work a ventilator in the flue in mild and windy weather, and in such a case it must perforce be closed. Such a chimney, however, will be found to draw somewhat powerfully in calm and cool weather, and during this time the ventilator in the flue can be made to do good service in the ventilation of the room. Unless the valve or valves of a flue ventilator are extremely delicate, the latter is of no use whatever, and its office in the flue is a sinecure. If the valve is very delicate, it will respond to every movement of the door, and be liable to play somewhat if the windows are open. This is why it has been recommended that flue ventilators shall have an arrangement for keeping the valves closed when required, and an additional safeguard is to thread the valve with wool so as to deaden the sound when the valve strikes the frame of the ventilator. Again, in very mild weather, when a small fire is necessary if only for appearance' sake, and the room is rendered close and oppressive in consequence, the most delicately poised valve will not be of much service—hence it has been suggested that provision shall be made to hold the

valve more or less open when required so as to enable the air from the upper part of the room to escape more readily. It has been mentioned, and deserves to be repeated, that self-acting ventilators in our most variable climate are of little value, *because they are inoperative when their action is most required, and this is especially the case with ventilators in the chimney-breast.* The author strongly recommends that a flue ventilator be fixed in every living-room, and that the tenant shall take such interest in the apparatus that he knows by experience just how, when and under what conditions it can be used to the best advantage. It is further suggested that if the chimney has a good draught, it should be swept regularly so that a flue ventilator either with or without a valve can do its best under the circumstances.

It is expected that the good housewife will enter a strong protest against the above conclusions, and point out that flue ventilators have generally a dirty appearance. The frame or border around the orifice of the ventilator is blackened, and sometimes the face of the wall, and, not unfrequently, the ceiling directly over. These two objections are somewhat weighty at first sight. With regard to the former, the blacking of the frame or wall immediately around the orifice of the flue ventilator does not necessarily imply that the smoke comes out of the flue and is the cause of the mischief. On the contrary, this blackening is often the indication that the flue ventilator works, and that probably it is one of the cheap and nasty copies of the Arnott pattern which allows much air to pass without moving the valve. This blackening around the orifice of the flue results generally, if not entirely, from the movement of the air in the room towards the outlet-flue ventilator, and is caused by the smuts (principally from the outside air) striking against the frame or wall around the ventilator. Wherever air moves rapidly and impinges at an acute angle against a hard surface, the smuts floating in it more or less blacken that surface. For instance, the author was consulted with regard to black marks on a ceiling painted white, under and close to which electric lamps

had been fixed, and these marks were found to be due to the smuts in the current of air which was caused to impinge upon the ceiling in consequence of the air being heated by the lamps close underneath.

When a flue ventilator belches forth smoke into a room, the latter colours the top border or frame of the ventilator more *brown* than *black*, and if the chimney-breast ventilator is fixed near the ceiling, the ceiling is also stained *brown*. It will be found on inspection that such a ventilator is imperfect and does not close against the back draught. But the chief mischief results usually from the chimney being allowed to be so choked up with soot that little room is left for the air and smoke to get through, hence the defective ventilator is responsive to every movement of air, not only by the door, but even by persons, especially ladies, moving in the room. As stated already, the ventilators should close perfectly, and any trouble which may result from a defective flue, or from the negligence of the tenant, would be provided against.

When a large family assembles in a small room, it may frequently happen where there is no chimney-breast ventilator that they sit there for long periods with less than 200 cubic feet of air per hour per person, and as double this quantity can be obtained by the use of a flue ventilator in five chimneys out of six, it will be seen how advisable it is that there shall be one fixed in every living-room. Ventilators of the Arnott type are not ordered by many architects, whilst speculative builders dispense with them probably on account of the trouble and cost. There are two reasons, perhaps, which account for the flue ventilators being less frequently adopted in buildings which have been erected during the last fifteen or twenty years. The first is that the self-acting valves used were not sufficiently delicate to enable an appreciable volume of air to pass through, and the second reason is that *fanciful and most unsuitable grates which will not work a chimney-breast ventilator have become fashionable.* If the tenant will look after his own health the adjustable

door ventilator, Fig. 3, is to be recommended. The housewife might fix a bracket just above the frame of the ventilator and let this project 6 inches in front. Fringe some 7 inches deep could be nailed along the front and two sides of the bracket, and this would nearly hide the ventilator and prevent the blackening previously referred to. The bracket could be spring-cleaned with the rest of the furniture, and a further touch in the autumn would remove much dust.

There are other grates more suitable to work a chimney-breast ventilator than those with movable canopies, because canopy grates with slanting Teale backs are not at all adapted for the purpose. Grates which are too open and have much space above the fire, grates of the old-fashioned type and all which do not direct a current of smoke underneath the flue, are not suitable, but only those which have dampers, valves or some other contrivance immediately above and under the centre of the flue, by means of which the current of air and smoke may be checked and regulated. These are the best for the purpose, although it will be found to be true generally that where a chimney "draws" well, a chimney-breast ventilator can be fixed in the flue with good effect.

Before leaving the subject of chimney-breast ventilators, it may be well to point out how their general use would not only lead to the atmosphere in living-rooms being much less polluted, but also greatly prevent the spread of consumption and other diseases which are fostered by impure air.

With regard to the cubic space allotted to each person in dwellings no definite order is in force, providing the buildings are not used as common lodging-houses. In reference to the latter the Local Government Board recommend 300 cubic feet per head. This is none too liberal, as it means that four persons may sleep in a room 12 × 10 feet if it is 10 feet high. In some towns twice the area is allowed, whilst in London as low as 240 cubic feet per head is permitted. In a civilised community it is questionable whether less than 400 cubic feet

should be allowed unless efficient mechanical ventilation was provided. When one considers the rooms occupied by the families of the poor, cases in which ten persons perhaps are crowded into one room having a cubic capacity of less than 2,000 cubic feet, it is a marvel how it is possible to be healthy at all. Hundreds of such families cannot afford to have two rooms, and if the authorities interfere it only means that the poor people have to leave the frying-pan for the fire. Still there is no doubt that something should be done especially to succour those who tend so greatly to keep up the figures of the birth rate whilst the majority of the population are doing their best to bring it, as in France, level with the death rate. So far as the middle and upper classes are concerned the cubic space allotted need not be inquired into as it is usually ample, but in the dwellings of the poor something should be done to devise methods to accommodate large families at a reasonable rent.

When the air outside is cold, it is not advisable to open a window or windows somewhat widely with a view to supply the fire more freely and get an extra volume of air into the room, especially if there are reasonable provisions in the form of chinks and fissures around doors and window sashes to feed the fire. The cold air immediately flows down to and along the floor in the direction of the grate, giving rise to cold feet and discomfort generally, whilst the air in the part of the room farthest from the windows, and where the occupants prefer to sit for comfort, becomes stagnant, with unpleasant see-saw movements supervening, owing to the irregular pressure in the room. It is best, therefore, to subdivide the incoming air as much as possible, and it is not wise to get the supply from one or two large openings. The friction which arises when the air passes through small crevices is considerable, and immediately a large opening is afforded, no air practically gets in through the chinks. If a window is opened, it is best that the upper sash be lowered and that the opening is not more than one

inch at the top, unless the weather is mild or warm. In the latter case, should the temperature outside be 65° F. or more, the lower sash can be raised and the upper sash lowered, so that one covers the other. It is best, however, that the space beneath shall exceed that above the upper sash by about one-third. The tendency will then be to expel the vitiated and warmer air through the opening above the upper sash. A word of protest may be in place here against the use of perforated insertions in the bottom of window blinds and the introduction of a lath of wood some 6 inches, 9 inches or more, from the lowest end with a view to prevent the insertion being wound upon the roller. If the sun is not shining upon the windows and all the light possible is needed, the use of so many inches of insertion, however artistic it may appear, is a mistake, but the evil is much more apparent in the summer when, the upper part of the window being opened, practically the whole area is occupied by the portion of the blind which cannot be wound up. The old-fashioned blind with the lath at the bottom is much more sanitary. Again, it is often imperative to draw down the blind in town houses to prevent persons looking in. To make this necessity less unpleasant and prevent the air in the room becoming stagnant, the blind should be fixed to the roller at the upper end by two or three stout canvas webs one foot in length, so that if the blind is drawn down low enough the upper part of the window can have a *free* opening to the outer air. For summer use this arrangement is excellent both as regards comfort and ventilation. When the temperature outside is below 55° F., it is well to begin the distribution of the air, because, generally speaking, a fire will be lit, and the air from outside will be cold enough to give rise to draughts. If the temperature outside is 40° or less, the windows can generally be closed with comfort and the possibility of fair ventilation. Where there is only one window and it is small it is better to fix an inlet ventilator of the Sheringham type near the ceiling with some provision for subdividing the incom-

ing air, rather than open the window widely, because there will be much draught experienced.

Dr. Bird suggested a simple expedient for introducing a little fresh air between the two frames of the upper and lower sashes. A block of wood from 3 to 6 inches deep is placed beneath the lower sash, then air can gain admission between the middle bars of the sashes. From some years' experience of the use of these blocks in class-rooms the writer cannot speak in their favour. Fan lights above the windows are much more effective, but these are rarely supplied in dwellings. It is questionable whether any much better method of introducing inlet air can be devised than by opening the top window sash one inch or more according to the temperature of the air outside. The main point is to let the air in as near the ceiling as possible so that it shall be tempered somewhat before it gets to the occupants, and in its fall to the floor.

Louvre panes in windows and other forms of glass ventilation are useful for supplying a small quantity of air continually where the window surface is small, but for dwellings a Sheringham valve or other wall ventilator of that type is more permanent and less liable to injury.

In a previous treatise the writer referred in detail to the Tobin inlet shafts without recommending their adoption for public buildings. They are not recommended for dwellings because it has long been recognised that they must be fixed much higher than was thought necessary in Tobin's time, and because the Sheringham valve, Fig. 1, is a cheaper and more simple arrangement and calculated to give rise to less draught. To introduce air near the floor level and cause this to pass up through a tube which takes up unnecessary room and causes much friction upon the air coming in is stupid in the extreme when the wall can be pierced where the air is wanted and no tube or other obstruction placed in the room.

This subject of inlet air is one surrounded with considerable difficulty. If provision was made for warming the air

before it came into a room, the chief difficulty would be overcome, but in ninety-nine cases out of a hundred inlet air is admitted in its raw condition into the living-rooms of private dwellings. Should the room in question be of fair proportions, 18 by 15 feet for instance, and there are three pairs or more of small window sashes, or two or three of larger size with one door, the volume of air leaking around such extended surface is not only sufficient to feed the fire, but the air coming in is so well distributed that draughts are reduced to a minimum. A room of this kind with a flue in an inner wall is very comfortable generally, and there is no need for inlet ventilators. If the room was provided with a suitable grate and a chimney-breast ventilator, it could be warmed with far less coal and the ventilation greatly improved. When the space beneath the door of a room is considerable, it is advisable to reduce this somewhat, so as not to get a severe draught in the direction of the fire, because of all draughts this is perhaps the most trying for the occupants. The inlet air getting into a small room through the crevices around two little sashes is generally very insufficient to feed the fire, and large volumes have to find their way in around and under the door. The flues in these rooms will generally work a chimney-breast ventilator if they are swept regularly, and, by those who have experienced the intolerable draughts which occur in very cold weather in a room 10 or 12 feet square, the comfort which results from the adoption of a flue ventilator will be greatly appreciated. In such a room always fix a Sheringham valve, if possible, to supplement the air supply coming in through the crevices around the one window, so that the air rushing beneath the door may be reduced in volume; but a grate which checks the air going up the chimney and a suitable flue ventilator are invaluable in this case, as the velocity of the air travelling near the floor can be reduced by one-half, and draughts prevented.

CHAPTER V.

AIR INLETS AND OUTLETS (*continued*).

MUCH has been written recently about the diffusion or effusion of air through porous material, and sanitarians have strongly advocated that walls and ceilings shall not be painted, papered, varnished or rendered in any way impervious to air. Whilst admitting that much air and impurity can and does pass through a porous ceiling and into the room above, it is not so evident that great benefit results from leaving the ceiling in a porous condition. The space between the ceiling and the floor overhead becomes filled with impure air, which by slow diffusion finds its way into the bedroom above after the occupants of the living-room have retired for the night. It is much preferable, therefore, that the impurities shall be drawn into the chimney by a flue ventilator. Notwithstanding what has been just stated, ceilings which are simply whitened and left in the condition of greatest porosity, have other healthy attributes and are to be recommended. If a house is well built, it is to be feared that the finishing of the walls, as practised to-day, prevents much diffusion of air through them ; and, although some little does find its way in, the volume is so trifling as to be disregarded in estimating the inlet air which enters a living-room from without. Apart from this conclusion, however, a porous wall is advantageous, and where there are damp courses to prevent water getting to the walls below, porous walls are usually the driest and the healthiest. Unfortunately, most of the air passing through a wall from the outside is induced to permeate the

porous material chiefly according to the pressure of the prevailing winds, or by reason of the appreciable difference in density due to the temperature outside being much lower than it is inside, so that the benefit which would result if there was much difference during mild and muggy weather is not experienced.

It has been stated that the air supply of a room should be as subdivided as possible, so that draughts shall not occur in cold weather. To this end, numerous devices have been suggested, and one of the most effective, probably, is that the cornices shall be perforated and the inlet air admitted through the perforations. The method is good, and sound as far as the distribution is concerned, but the difficulty is to provide a channel for the air which can be cleaned and in which the smuts will be prevented from getting through the perforations to blacken the edges of the cornice as they pass. Unfortunately, this blackening will result to some extent even if the air is washed, as small smuts frequently escape capture by the water.

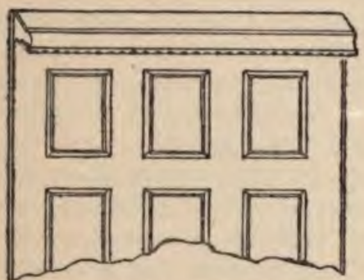

FIG. 10.—Shelf Arrangement for Distributing Inlet Air.

The better plan is to fix a small shelf, Fig. 10, to hold pottery, and the air space is to be provided under the shelf and behind the arrangement which is left hollow for the purpose. Inlet air can travel behind and find its way into the apartment through small perforations in the front, or the air may be allowed to escape at the top and bottom. Furthermore, the whole device is to be so suspended that it can be taken down for the purpose of cleaning. The air from the outside is to be admitted through narrow bricks, finely perforated, fixed at frequent intervals, and no plaster is to be behind this inlet

ventilator. If these air bricks are in the outer wall and face a cold quarter the perforations must be small, as when the wind is in that direction the volume of air getting through in severe weather will be greater than those who study comfort more than fresh air may desire. To provide against this contingency the shelf arrangement should be so fixed that it can be screwed up tightly against the wall when required, and thus prevent an unreasonable volume of air coming in during severe weather. Where a room is lit from the end and the window space is confined to that position, the adoption of such a shelf ventilator along the side of the room fronting the fire will give satisfactory results. It should not be forgotten that owing to the quantity of smuts present in the air of large towns, perforated cornices and other inlets provided with means of greatly subdividing the inlet air *are not very suitable, unless there is some way of cleaning them so as to remove the smuts and dust.* The shelf arrangement when it is fixed above a radiator is best set upon the top of panelled woodwork which reaches from the skirting to the top of the shelf. If the radiator is in a drawing-room where a delicate paper is used the circulation of the heated air will in time slightly soil the paper. To avoid this the woodwork is recommended, and this can be painted if necessary to match the paper.

The late Dr. Reid recommended[1] that air might be admitted through the skirting. In this case, of course, it would have to pass first through the air grids placed in the outside wall of the house to ventilate the floors underneath. This is a satisfactory arrangement provided the house was built upon solid ground, and not upon land which has been filled up with scavenger and other refuse material. When the earth under the floors is dry and satisfactory there is no reason why air should not be taken from under the ground floor, as it is a simple, effective and by no means expensive device for the ad-

[1] *Illustrations of Ventilation*, p. 90.

mission of inlet air. If the grids outside are made on the hit-or-miss principle, they can be closed in cold weather. If the weather is very severe, boards or stones can be placed in front of the ventilators which can be rendered air-tight with a little soft material. In this way the volume of air coming in can be regulated from the outside. After passing underneath the floor, the inlet air is admitted through the skirting by small holes with a centre bit one quarter of an inch in diameter at one quarter of an inch intervals. These holes are bored through the lower part of the moulding. In this case the skirting should stand about one quarter of an inch from the wall, and such a distance can be easily obtained, because the plaster is dispensed with beneath the skirting. It is best to admit the air all along the side of a room opposite the fire-place if it is practicable, allowing the skirting near the part of the room which is most desirable to sit in to be free from perforations. This device is very useful in small rooms, but the way the air is let in does not conduce so much to the diluting and removal of the impurities as when it is introduced through the cornice or other arrangement near the ceiling.

Another method for admitting inlet air much subdivided is facilitated by the ventilators under the floors in houses which have been jerry built. In such houses there are air spaces between the boards, and where these occur, and the rooms are small, the tenant will find it possible to prevent much draught coming in through windows and around the door in particular if he keeps the crevices between the boards free from dust in those portions of the room where the occupants rarely sit. The author had a room built for determining the lighting power of gas and other illuminants, and it was found to be well ventilated through the spaces between the boards which had shrunk badly. In cottages and small villas the admission of air through cracks in the floor or through the skirting adds greatly to the comfort of the occupants in cold weather. When the skirting is used to admit and distribute fresh air, it should not be nailed to the

wall, but fastened by screws so that it can be taken down at intervals to remove the dust, etc., collected behind. It is poor people who have the largest families and the smallest rooms to live in. What a boon to the community it would be if flue ventilators were adopted generally, whilst every small room with but one window should have an arrangement near the ceiling for the admission of much fresh air through such small perforations as shall render draughts practically impossible.

Outlet Ventilators.—The efficacy of the chimney-flue to remove air and smoke and ventilate a room has been mentioned in detail, and there is little more to be added. A flue 9 × 9 inches is only effective in mild weather to the extent of 3,000 to 6,000 cubic feet per hour. During some of this time the window could be opened somewhat widely and aid in the ventilation of the room. It will be seen, therefore, that if a room has to accommodate several persons and exceeds 20 × 15 feet, it is advisable to make the flue 14 × 9 inches.

Of late years some flues in houses and offices have been constructed with enlarged spaces or smoke reservoirs some 2 feet above the entrance into the flue. These receptacles for soot also form extension reservoirs which are not only useless, but very detrimental to the satisfactory working of the chimney. Where the winds aspirate near the ground level, the smoke in such reservoirs is easily expanded, the result being that puffs of smoke are drawn into the room.

All that is necessary has been said in the text already about chimney-breast ventilators, so that attention can now be directed to those flues which are built in the walls by the sides of the chimneys, and are more or less warmed by them when there are fires in the rooms. These outlet air-shafts or tubes are either 9 × 9 inches like the chimneys, or consist of glazed earthenware pipes from 6 to 9 inches in diameter. At the bottom end of the flue where it starts from the living-room there is usually some valve or valves, and frequently mica plates are used for the purpose. The idea of removing the foul air

near the top of the room is excellent, but it is not practical to do this by means of a separate outlet flue in a room where a fire is burning. This is so because the pressure is much less in the room than it is outside, owing to the friction which the inlet air encounters in getting through the chinks and crevices. In those rooms where the flues have mica valves at the bottom, neither good nor harm is effected by the outlet flue, because no air passes away through it. This is made doubly sure by reason of the tension or partial vacuum in the room which sucks the valves or mica plates inwardly and holds them tight so that air cannot pass, but where the outlet flue is open from bottom to top it will be manifest that no air will go up the outlet flue if the chimney-flue can help it. Should the chimney-flue be foul with soot it is not unlikely that the outlet flue will then aspirate as powerfully as the chimney itself, the result being that when the outlet gets the mastery the fire smokes, and when the fire is strongest no air goes through the outlet. If a window is opened 6 or 8 inches, there may be enough pressure to work the outlet flue in very cold weather, but, of course, the inmates rarely can tolerate a window being open under the circumstances. If the weather is mild and the outlet flue has mica or other valves at the bottom, there will not be sufficient pressure to cause an upward current. Nor will the adoption of a grate which heats a current of air coming from the outside get over the difficulty. If there are no valves and much warmed air comes in, there will be a stubborn fight between the chimney and the outlet flue. The latter will cause some vitiated air to pass outwards and increase the tension upon the air in the room. As a result, the velocity of the smoke passing up the chimney will be reduced too low, and the soot will be deposited in such a finely divided condition that it will at first fill up the flue rapidly, and subsequently tumble down in great avalanches at frequent intervals. Assuming that the flue is in the inner wall, a separate outlet flue even though open throughout is a nuisance, and far less effective to remove vitiated air than a

ventilator without a valve fixed in the chimney-breast. Again, if as hinted already, there are valves at the bottom of the usual type, the outlet flue does not work at all, and the valves only move if there is wind pressure through the windows, or when the door of the room is opened suddenly.

The author experimented with outlet flues in a friend's house some years ago. These flues began in the chimney-breast of each room and were supplied at the bottom with a modified form of Arnott valve. When the wind was choppy, considerable aspiration occurred at the upper end of the outlets. On more than one occasion the aspiration at the upper end of the dining-room chimney and of the outlet flue was so considerable that puffs of smoke came into the room each time a lull occurred in the blowing of the wind. Immediately the wind pressure was released, air descended the inlet flue, perhaps half-way down, causing the ill-fitting valve to clap considerably. After the cold air had travelled down some distance, it became warmed by the brickwork next to the chimney, with the result that an up current was started, as was evident from the movement of the valve. This upward current caused the air in the room to be under increased tension, but as the chimney had the stronger ventilating power, the velocity became too slow in the outlet flue to keep back the denser air at the top, the result being that cold air descended the flue again for some distance until it was heated sufficiently to rise upwards. When no appreciable wind was blowing, the state of things described was always repeated at intervals in cold weather as long as a good fire was burning.

The question may be asked, perhaps: "What would be the result if self-acting pneumatic pumping cowls were used on the top of a separate outlet flue?" In a previous treatise[1] the author dealt with a somewhat similar question, only it was in relation to public buildings, and showed that the aspirating

[1] *The Ventilation, Heating and Management of Churches and Public Buildings.*

efficiency of the so-called pneumatic ventilators was, fortunately, far less than if the wind was allowed simply to blow across the open mouth of the unprotected outlet. Were it otherwise smoky chimneys would be even more in evidence in those cases where such ventilators are in position. Revolving cowls do not usually aspirate much, and are practically inactive.

In the case of Board Schools separate air outlets are demanded by the authorities. When visiting Board Schools for ventilating purposes the author has found that in numerous instances the air outlets are carried up by the side and to within a trifle of the top of the chimney-stacks and then covered over. Iron gratings are provided in the sides of the chimney-stacks with a view to the foul air passing into the atmosphere through them. When the wind blows against these gratings, so much air gets into the flues that the aspirating power, if any existed, is overcome and down-draughts are prevalent. This method of finishing off the outlet at the top has been adopted by some architects in the houses they have designed, and can only give rise to irregularity of pressure in the room underneath with considerable sweeping of cold air at frequent intervals when the wind blows against the end of the chimney-stack and aspirates, somewhat powerfully, upon the outlet gratings. If separate outlets were workable when fires are used, it would be better if they were finished off with chimney-tops which did not aspirate, and which may be shorter by a foot or more than those on the chimney-flues. If the rooms in houses are heated by hot water or electric radiators without fires, ventilators in the chimney-breast will form reliable and efficient outlets, and there will be no necessity for separate outlet flues.

Whenever a new book on lighting and ventilation appears, it does not seem orthodox to dispense with some description of the ventilating gas-burners which have been placed upon the market. These will be mentioned again if their illuminating value demands notice, but although so many kinds have been tried, there are few instances in which one of them is used to-day in

dwelling-houses. Such gas-burners are more or less enclosed and connected with an outlet shaft passing through the ceiling of the room. The heat created by the gas induces a current of air to travel outwards through the pipe around the gas-burner. Unfortunately, for the reason already mentioned, the outlet shaft warmed by the gas-burner pulls against the chimney, and if the gas effects the removal of some of the vitiated atmosphere it is probable that it will be equally effective in causing the fire to smoke. Attempts have been made to assist extraction through separate outlet flues by using jets of gas underneath the lower ends of these flues. If a window is opened wide in mild weather the outlet flue will work, but if it is cold and the windows are closed or a strong wind is blowing the fire will smoke as soon as the gas jets are lit.

Now that the electric light is becoming more generally adopted, it may be suggested that a small fan fixed under the separate outlet would be effective. It certainly would if the windows could be kept open sufficiently wide to feed a fire, but the moment they were closed the fan would overcome the power of the chimney-flue, unless the latter was large and very high, and bring the smoke into the room. It might be suggested, however, that a separate flue would be very useful in summer for the removal of the vitiated atmosphere from the upper part of the room, especially if there was a small fan adopted. The flue would be of little service in warm weather, and a fan could be applied then to drive air through a chimney-breast ventilator just as easily as through a separate outlet flue.

If separate outlet flues carried up by the chimneys are provided in a house where dog grates, grates with hobs, hearth fires or any grates which do not send hot currents of smoke up the chimney are in evidence, the tendency to smoke which characterises such grates when no separate outlet is furnished becomes more pronounced when such an outlet exists. Architects will act wisely, therefore, if they dispense with separate outlets altogether in living-rooms of reasonably small propor-

tions heated by ordinary fires, and rely upon a larger chimney with a flue ventilator when much air is required, due consideration being also given to the suitability of the grate, especially in cases where the flues are in the outer walls.

Where a small room or workshop has been built, and it is heated by a gas stove or electric radiator because there is no fire-place, the air will be very stagnant when the door and window are closed unless some top ventilation is provided. A tube from 9 to 12 inches in diameter having a valve at the upper end which can be closed in very cold weather will be found sufficient. If the room is used for periods of some duration, the method of admitting air through the skirting, or, better still, between boards which have shrunk or have not been fixed too closely, will be found satisfactory.

In the case of a billiard-room heated by hot water and which has no chimney-flue, the outlet may be through movable lights in a closed roof, or if there is no top light, through a 10-inch ventilator fixed in the centre of the roof. The tube of this ventilator must have a regulating valve at the top which will close perfectly in very cold weather. Where a billiard-room has no other room above it, it is best without a ceiling. In such a case the rafters should be boarded over and carefully covered with good felt.

By reason of the use of central flues or ventilating shafts in large buildings, it has been suggested that the principle might be applied in the case of dwellings, such as flats for workmen and the like. The writer does not consider the plan sufficiently feasible or workable to give much space to its discussion. Where a building was under the direction and supervision of one capable man, it might be possible to work many fires by a large central shaft, but the varying condition of the fires, some evolving great heat, others nearly exhausted and others which are unlit having their dampers left open through carelessness, might so reduce the ventilating power of the shaft that some flues would work with much difficulty, and have little power to

remove vitiated air. Again, the top of such a shaft would require a valve or some other arrangement whereby the area of the outlet would be regulated according to the temperature of the air outside, and it would be necessary also to have a person who had sufficient physical knowledge to regulate it. A separate flue for each room is preferable, and, it is to be feared, the only workable plan for our present social and economical arrangements.

Before leaving the subject of the inlets and outlets it may be well to deal with a case which not unfrequently arises now that the open-air treatment for consumption is so generally adopted. Some member of a family suffering from that complaint decides to be treated at home, or perhaps necessity demands it—what inlets and outlets ought to be adopted so as to ensure the largest volume of fresh air in the living-room? If there are two windows, one in the end farthest from the fire and one nearer to it, it is best to open the former somewhat wide at the bottom as well as at the top, and the latter some two inches at the top or more according to the severity of the weather. The window farthest from the fire should be opened wide enough to supply the fire and afford an extra volume to drive out the vitiated air at the top of the second window. The direction of the wind is, however, a very important factor, and the tenant should know from what quarter the wind blows. If that direction was right against the window nearest the fire, no vitiated air would pass outwards, but cold air would get in. If the occupants can stand the introduction of air through this window, either at the bottom or top of the sash, the ventilation of the room will be assured if the other window is opened somewhat at the top. When large volumes of air are desired, such as for this treatment, cornice inlets, Sheringham valves and distributing air inlets are of secondary importance, and if they are not in existence, it is questionable whether it is worth going to the expense to fix them. The windows are the best inlets, but the direct pressure of the incoming air must be broken,

otherwise neither the fire nor the illuminants will stand the irregular pressures and draughts which will be experienced at intervals. The old method of raising the lower sash and placing a piece of wood 3 inches thick underneath will be found useful when the temperature outside is below 32°, but may be regarded as very inadequate at any temperature above. To break the force of the air admitted at the bottom of the window, a blackboard held on the ordinary tripod will be found effective. A screen which can be raised or lowered like Fig. 11, made of transparent material, is useful to stand about a foot in front of the lower sash of the window, and an arrangement of similar material for suspending before the top of the upper sash, but far enough from the ceiling that the vitiated air will escape over, is very useful where there is only one window in the room. By the aid of such upper screen standing a foot from the window frame, it is possible to admit fresh air and allow vitiated to go out through the upper sash of the window. With regard to separate outlets by the side of the chimney-flue, if there is one without valves it may be left as it is, the only drawback being that if the windows have to be shut at night for protection the separate outlet will pull against the chimney, and when the fire is low cause smoke or sulphur to get into the room. If a chimney-breast ventilator is fixed in the flue and it has mica or other valves the probability is that the unceasing clapping of the valves at times will greatly irritate the occupant, and lead to the ventilator being covered over by pasting paper in front. The fresh-air treatment aims at keeping the pressure in a living-room great enough to expel the vitiated air through the tops of the windows, and the chimney-breast ventilator, if it has no valve, will probably let so much cold air into the chimney as to seriously impair the draught of the fire. Again, the chief difficulty experienced will be to *maintain the temperature* of the room at a reasonable point in cold weather. It will be abso-

FIG. 11.—Air Screen on Stand.

lutely essential that the fire shall burn brightly and hot, and it is in a case like this that the value of a grate which can be regulated as to the volume of air going up the chimney, and which is so constructed that the air will keep the front of the coal as nearly white hot as possible, is appreciated. If the grate has no outlet valve or regulator, or is too open, much cold air will pass up the chimney and the greater part of the sooty matter will be deposited. To give the patient the best chance, have the chimney swept once in two months at the outside—once in six weeks would be better. A good grate which has a chimney-flue in the inner wall will nearly always work a chimney-breast ventilator with some effect, but it is best to make sure that the fire shall "draw" well and send out much heat rather than try to ventilate through the chimney-breast. During the autumn and spring it is possible to have much air passing through a room if a good fire is kept and considerable window space is open.

Inlets and Outlets for Stables.—Before leaving the subject of inlets and outlets a method of ventilating stables might be of service. These should never have rooms above them if it can be avoided, and if such rooms must exist, either for hay storage or as living-rooms, the boards should be carefully tongued and good ceilings provided. If there is a room over, the height of the stable should not be less than 12 feet. Within 6 inches of the ceiling and immediately above the windows a number of perforated bricks should be fixed at intervals of 9 inches, having perforations not more than half an inch in diameter. Immediately below the bricks on the inside, flaps or boards 4 feet long, hinged at their lower edge, should be held by a cam arrangement, so that the board or boards can be closed perfectly or left as much open as desired. Each board covers four air bricks. These bricks are best used in both the front and back walls, and the boards or flaps should be made of well-seasoned wood and fit accurately. The stable should have narrow lights above the horses' heads and immediately

under the air bricks. Two such lights to a loose-box and one above each stall, all capable of being opened for summer ventilation. The door of the stable should have a movable fanlight fixed over it, and there should be other windows for well lighting the stable behind the stalls. Windows whose upper sashes are on the fanlight principle are well adapted for stables, especially those intended for lighting behind the horses in the stalls.

CHAPTER VI.

SMOKY CHIMNEYS.

Of all the troubles which the householder has to face there is none so unsatisfactory as smoky chimneys, especially if these are situated in outside walls. In the latter case the soot is deposited in the flues in a very finely divided state, hence the slightest movement in the chimney brings down a flood of soot dust which, becoming ignited as it passes the fire, sends a shower of sparks sometimes right across the room, rendering everything in its course black and ill-smelling. The first shower of soot is generally the prelude to the fall of more, and the winds which usually overturn the ventilating power of the chimney and commence the mischief seem to take pleasure in sending gust after gust of smoke into the room, so that altogether the mistress and the servants have a very bad time. Those chimneys which smoke because the wind aspirates the air which would otherwise get into the room through the crevices around the windows, etc., may not have the soot so finely deposited nor so prone to fall, but when a puff of smoke gets into the room the outer atmosphere descends the chimney somewhat from the top, and if the grate smokes badly, it descends still more as puff after puff gets into the room. Once the cold air from above reaches the fire it is almost impossible for the smoke to get back into the flue, owing to the peculiar construction of many of the grates, and the state of affairs is disagreeable in the extreme.

A word of caution may be salutary at this point, and the

would-be tenant of a house, especially if he is likely to be a purchaser, should ascertain for certain how the chimneys act. If there are zinc or galvanised iron tubes, lobster cowls, tall-boys, revolving cowls or such-like contrivances upon the chimney-tops, he may be certain that something is wrong. If on examination the grates show that they have been drilled to facilitate the hanging of sheet-iron discs in front of the fire, it is doubly sure that serious smoke trouble will be experienced. He will be wise if he consults some one versed in the matter to ascertain if the sanitary and other conditions are in order. It may be mentioned that there is no necessity for ugly bends and cowls upon chimney-tops, or that any chimney should smoke. A good grate suitable for the situation and a permanent terra-cotta chimney-pot, which will prevent wind suction, being all that is wanted, providing, of course, there is no obstruction in the flue and a reasonable volume of air gets into the room. The purchaser of a house, therefore, should stipulate that the grates shall be such that the chimneys shall not smoke when a good wind-resisting permanent pot is in position.

Another word of caution is necessary at this stage. If the householder is bent on removing the cowls off his house, and has fixed a good grate and obtained a satisfactory terra-cotta pot, let him employ a man whom he can trust to fix the latter. Should the tenant select the pot himself and employ a man to fix it who receives an extra discount on every cowl of a certain pattern which he places in position, it is not unlikely that a nest of hay made by a wingless bird will accidentally (?) find its way into the chimney-pot, and cause the chimney to smoke, with the possibility of condemning both grate and chimney-pot. The author has found this disreputable trick done somewhat frequently, and the owners of flats and suites of offices will find it much to their advantage if they call in some one who knows whether there is any real cause for the smoke trouble, or whether some foreign matter like a wisp of hay or straw or shredded wood has been introduced, so that the parties con-

cerned might mutually benefit, and further work and fees be obtained. Let but one cowl be fixed on top of a large building, and it is surprising how soon another chimney is found to be faulty, and the owner should have the chimney swept and the pots examined before proceeding further.

The condition of the chimney-tops in London is such as defies description, and what it will eventually be it is difficult to prophesy. Zinc and galvanised iron tubes and cowls are upon the market having their upper portions movable and fixed by bolts. If the 6-foot cowl first placed in position to try its effect does not stop the smoke trouble in the room underneath, another and longer top, perhaps, 6, 12 or even 18 feet, is bolted on. It has been stated that the higher the chimney the greater the ventilating power, hence the lengthening of a chimney is usually a ready means of increasing the ventilating pressure. The effect of this addition may not be visible for a time. Perhaps the chimney was one in a suite of three offices, and by the additional length what was previously the weakest chimney is converted into the strongest. The next time a wind blows which adversely influences one of the two other chimneys, this flue commences to smoke. Again the tube maker is consulted, and he thinks a 6-foot cowl must be placed in position. This cures No. 2, but unfortunately the extra length of flue has overcome No. 3, which smokes now. A long cowl is placed on No. 3 and all appears well for a little while until the wind affecting No. 1 blows lustily, then it is found that it smokes notwithstanding the added length of the chimney. By this time, probably, the owner or occupier who has to bear the expense is thoroughly aggravated, and sends for an expert, who tells him that there was no reason whatever for this metallic tube addition either with or without a revolving cowl.

It not unfrequently happens that when once these tall-boys and cowls are fixed upon a block of flats, and long lengths of tubes added until the two or more fires burning at the same time draw—for this can be done by greatly lengthening in

some cases—it is the means of causing chimneys to smoke in other parts of the building, getting air from the same corridor, which were perfectly good before. When tall-boys and cowls are added to one or two additional chimneys, the whole, perhaps, or nearly all the flues in the building are doomed. The great volume of air necessary to feed the chimneys whose ventilating power has been so greatly increased is not provided by the leakage around doors and windows, because of the increased tension or partial vacuum which has been formed, and fire after fire is made to smoke.

The owners of such buildings should grasp the truth that what was wanted was not higher cowls to draw more air out of the room, nor was greater ventilating power necessary, but some means of checking the *overdraught* in such high chimneys—in other words, the chimneys wanted shortening, *if that were practicable*, instead of lengthening. In some cases the grate was unsuitable, and likely enough want of air into the room was the *chief fault* in many instances. If the owners of new blocks of flats and offices set their faces against iron tubes and get sound advice when a flue smokes these ugly defacers of architecture need not be placed in position at all, and immense sums of money saved eventually. Some of the cowls fixed upon buildings in London cost £3 or more by the time they are set, and, as the life of these rarely exceeds four or five years, a building with fifty or more chimneys is a little mine of wealth to the cowl makers and a serious annual loss to the proprietors. Unless chimneys rest against the pine end of a building which has been raised many feet above them, a good terra-cotta pot and a suitable grate are all that are necessary, and if the chimneys are so situated, iron tubes carried up to the top of the new building are as good as if surmounted by a revolving cowl, which is an unnecessary expense. If the owner of the house is not going to rebuild, it is best and cheapest in the long run to carry up a permanent stack at once, high enough to reach the top when a 6-foot pot has been added.

The consideration of the cause and cure of smoky chimneys being so important, it will be best to mention in detail the various faults which give rise to them and how to overcome the difficulties. They may be grouped thus: 1. Defects in the flue. 2. Defective chimney-pots. 3. Defects in the grates. 4. Defects in the room in question. 1. These defects may be due: (*a*) to the flue being too small; (*b*) to too many twists and bends; (*c*) to obstructions from dropped mortar and not being properly cored afterwards, or too sudden angles at the main carry-over or bend; (*d*) to the flue being in an outer wall and cold, covered with only 4½-inch brickwork, bricks porous and mortar made with sea-sand, giving rise to continual damp in moist or rainy weather; (*e*) the chimney being too short. Before discussing (*a*) it may be well to deal with the number of the bends and the angles. If the flue is carried across to another wall with a sharp bend and it has to go some distance nearly level afterwards, such a flue ought to be 12 inches square, and one 9 × 9 inches will probably give some trouble. A flue 9 × 9 inches is not too small for rooms up to 300 feet super, provided it is fairly straight and the main bend[1] is not at a sharp angle. If there is more than one bend, it may be advisable to have the chimney 14 × 9 inches until the first is

[1] With regard to the question whether every chimney should have a bend in it as stipulated by the authorities in London, the consensus of opinion probably is in favour of such a bend, but the idea is quite foreign to physical theory if not to common-sense. It is true that some chimneys which have bends do not smoke, and that some which are straight do smoke, but in the former case the bend saved the chimney because the flue was too large, and in the latter case the same fault was partly the cause of the mischief in consequence of a want of air supply in the room. When it is remembered that a sharp bend reduces the ventilating power of the chimney by from one-fifth to one-half according to the angle, it will be seen that it is not wise to have bends in a flue which is not greater than 9 × 9 inches. If the end of a flue is covered with a suitable wind-resisting chimney-pot, the flue can be straight no matter what its size may be.

passed, and 9 × 9 inches afterwards, so as not to restrict the air which is drawn out of a room. The last 6 feet of a flue, and in high houses from the point where the flue is vertical, should always be reduced to 9 × 9 inches if it is previously 14 × 9 inches. These remarks refer to ordinary rooms with ordinary grates. A very large kitchen range may require a flue 14 × 14 inches, but the last 6 feet of this chimney should be drawn in until it is not more than 10 × 10 inches at the top, and the diameter of the chimney-pot, if short, should not be more than 9 inches. For a range not more than 5 feet wide, a 14 × 9 inch flue will be found sufficiently large. It would not be wise to make the flues in the reception-rooms of a house too large, else the volume of air sucked out will reduce the internal pressure unduly and cause the fires in the rooms upstairs to smoke and probably one of those on the ground floor when three or more fires are going at the same time. A living-room 30 × 20 feet should have two fires with 9-inch flues, but if one fire only is provided the chimney should not be less than 14 × 9 inches. A 9-inch flue will do for a room 20 × 15 feet, provided the length of the chimney is not less than 25 feet. These remarks in reference to the sizes of chimneys are made because the flues are the chief outlets for vitiated air from the rooms, but they are also given because the question has not been much dealt with by other writers, and the author has often been asked for the information. In designing offices or flats the rooms which conveniently form suites of two or more should not have flues greater than 9 × 9 inches unless all the rooms are more than 20 × 15 feet. If three rooms form a suite and one of these is 30 × 20 feet it is far better to make the three flues 14 × 9 inches, although one office is only 14 feet square if the two smaller rooms open into the larger one. If the larger room has a flue 14 × 9 inches and the two others 9 × 9 inches, and it so happens that one of the small rooms has its flue in the outer portion of the stack above the roof, whilst the flue of the large room is between two flues right to

the top, the small room will be almost certain to smoke. A plentiful supply of air should be provided, but if the three offices are not above the second floor and no room exceeds 20 × 15 feet, 9 × 9 inch flues will do, all the offices having suitable grates and if possible a ventilator in the chimney-breast.

In reference to a flue smoking because it has too many bends (*b*), very few such chimneys are made now, but some are found, which, in addition to the bends, are roughly and badly made, the consequence being that the smoke makes its way up very slowly—these are sluggish chimneys. The practised hand will know that something is wrong with the flue after he has opened the doors and windows and carefully observed the effect. The result and behaviour of the chimney will be much the same in the case of (*c*) where there is a decided obstruction and narrowing of the passage from 9 × 9 inches to 9 × 4 inches perhaps. This chimney smokes worst in windy weather, but after it has been swept a fortnight it begins to give trouble, and subsequently more or less repeatedly. The smoke passes slowly up the chimney, and the top of the fire long after the tarry matter has been removed from the coal never gets bright red, but is somewhat black, showing that the products of combustion are not removed quickly enough to furnish fresh air. Rooms with such flues are close and stuffy with insufficient air moving. In the case of (*b*) very little can be done to improve the flue perhaps, but if the grate is not suitable and the air and smoke passing up are too cold, a grate which will send a hot current of smoke up the chimney should be fixed, and will give good results. It may also be advisable to place a tall chimney-pot upon the mouth of the flue if that is below the roof or in a position upon which the wind has much influence. In the case of (*c*) the same treatment as (*b*) received may relieve the situation if the flue is swept frequently. There is nothing like going to the root of the trouble at once, however, and there is no question that having found by a round iron ball

let down from the chimney-pot, or by the sweep's brush failing to get through, that an obstruction exists at a given point which has been carefully measured, a hole should at once be knocked into the flue and the obstruction removed. If the flue was otherwise good the cure may be perfect, but in any case it is the most sensible thing to do *first*. The author met with a block of flats which had obstructions in the chimneys at nearly every carry-over bend, and this drastic treatment was adopted and proved most successful.

With regard to (*d*) it rarely happens that flues in the outer walls are found in houses which are attached, because the chimneys are carried up in the inside walls. It is in detached and semi-detached villas and houses that they occur chiefly. These outer wall flues should be avoided in all cases where the architecture will permit, for the following reasons. Whether the walls in which they are carried face the north or south, east or west, the ventilating power of the chimney will be seriously impaired in consequence of the wall being outside and cooled by the atmosphere. Internal walls are warmed by the fires in the house and by illuminants, hence the smoke in the chimneys loses less of its heat in travelling from the fire to the mouth of the flue, and the ventilating power of such a chimney is relatively greater. When the wall faces the east or the north, and the wind blows upon unsheltered buildings, the ventilating power of the flue in such a wall is reduced to very small proportions, and so low that a sudden gust will overturn the current in the chimney, and cause much smoke trouble and nuisance. The very finely divided soot deposited in such chimneys, occupying so much space, soon fills much of the 9 × 9 inches of the flue, and the friction which the air encounters in passing through the constricted flue is nearly equal to the ventilating power left in the chimney by the cooling action of the air outside. These considerations show how probable it is that such chimneys will smoke and that avalanches of soot will frequently tumble down, whilst the various forms of tubes and cowls fixed

upon them indicate how real is the lack of "draw" or ventilating power. Unfortunately there is not only a lack of velocity in the column of smoke ascending the chimney, but the room itself cannot be other than badly ventilated when the fire is so frequently on the point of smoking and so little air ascends the chimney. No chimney-breast ventilator can be fixed near the ceiling with any certainty of action, but such a ventilator *should be fixed*—not one of the self-acting type which will never work in a chimney so cold—but one which can be opened by the occupants when the fire "draws" better, and shut closely when things are at their worst.

It has been mentioned more than once that the ventilating power of a chimney is usually proportional to its length, but this truth is less manifest in the case of cold chimneys than with flues in other situations. Still, however, when the bedroom chimneys are used it is found more difficult to prevent smoke trouble with these than with those from the reception-rooms downstairs, and gas fires are frequently adopted to overcome the difficulty. The want of "draught" in these short, cold flues and the fact that the air in a house is under slight tension causes the products of the gas combustion to pass into the room much as the smoke does when the fire is lit, and the use of gas fires under such flues is decidedly unhealthy. If a bedroom fire whose flue is in the outer wall is lit during the day when the fire is burning in the room underneath, the bedroom fire usually smokes with the least provocation, and if it does not, it shows that the bedroom grate sends a hotter current of smoke up the chimney, and such grates alone are suitable for these bedrooms or any other rooms on the upper floors. If the chimney in the outer wall happens to be damp as well as cold, the ventilating power is still further reduced, and more care is necessary to prevent smoke trouble. The tenant should always remember that an exposed chimney must be very cold unless warmed by the fire, and when the night has proved severe, and the fire has gone out early, the inside of the flue is

not much above the temperature of the air outside. If the temperature outside rises suddenly and considerably just before the fire is lit much smoke issues into the room. In the spring and autumn when the temperature of the air is above 45° there is also trouble in lighting these fires, especially during damp and rainy weather. A blower for temporary use will enable the housemaid to light the fire more easily, but during bad weather, if this blower is placed before the fire, the waste of coal is so great that it cannot be recommended with much confidence. A blower should be capable of adjustment and form a part of the grate. The top of the grate should be adjustable also, that as high a velocity as possible might be obtained at that point, then it will not be so easy to bring the smoke back into the room when the wind exercises suction upon the outside of the windows.

Referring again to the lighting of fires whose chimneys are either cold or smoke frequently, it is not wise to burn a newspaper immediately under the flue as is sometimes done, unless the chimney has been very recently swept, else the latter might be set on fire, but an egg-cupful of paraffin oil poured over the top of the coal and set on fire, first, will generally start an up-current in the chimney and greatly aid in lighting the fire. When a room is in want of air, the fire gives some trouble, even though the flue is in an inner wall. The opening of a window will stop the fire smoking when it is lit, unless the wind is troublesome, but as the soot in such chimneys is very bulky and finely divided a newspaper should not be set on fire above the coals. If the fire is refractory a little paraffin oil or methylated spirit will generally succeed best.

The question may be asked: "Why is it that some chimneys in the outer walls seem to have good ventilating power?" The reason is usually manifold. The wall is facing a warm quarter, or sheltered if facing east or north. No jerry-builder has been at work and the materials are good. The bricks are dry in character and non-conductors of heat. The mortar was

made with washed sand free from chloride of calcium, and the joints well filled and pointed. Some of these reasons may have been the results of accident, but they count notwithstanding.

The next consideration is how cold and smoking chimneys can be cured. After reflecting upon what has been stated already, it will be seen that the almost universal practice of trying to cure the mischief with a chimney-pot is not either a cheap or wise method of procedure. It would astonish many readers did they know how many kinds of chimney-pots had been fixed upon some chimneys, and the author once met with a case in which the maker of every known pot was asked to send his speciality for trial, and if it answered it should be adopted. No pot answered, because it was *not a question of chimney-pot at all.* The same may be said of some cold chimneys in situations where the wind exercises much suction. It is not an uncommon thing to find iron tubes 6, 10, 15 and even 20 feet high which have been fixed upon such chimneys, and Fig. 12 is a case in point evidently. This sketch was taken by the writer, and shows to what extent the lengthening of chimneys has been carried. The iron tubes are ornamented with rings and are 20 feet in length. They are fixed as shown to a house of considerable size at one of the seaside resorts on the south-east coast.

The cowl-setter could scarcely be expected to know much about the physical laws which bear upon such chimneys, nor is the owner of such a house wise in calling in a man who understands so little about the matter. Much more unwise, surely, to let him erect iron tubes fixed to the roof by iron stanchions and so frightfully unsightly, whilst a sum of money large enough to provide suitable and handsome grates which would cure the trouble permanently has been thrown away. Let it be clearly understood, however, that the value of a good chimney-pot is fully appreciated. These cold chimneys require the top of the flue to be well clear of the roof, and a good chimney-pot which will prevent undue wind suction will be found necessary as a

help and adjunct to the best grate if the chimney is a refractory one. A good chimney-pot is necessary, therefore, but if the grate is unsuitable it should be first replaced by one which will send the hottest current up the chimney. Common-sense

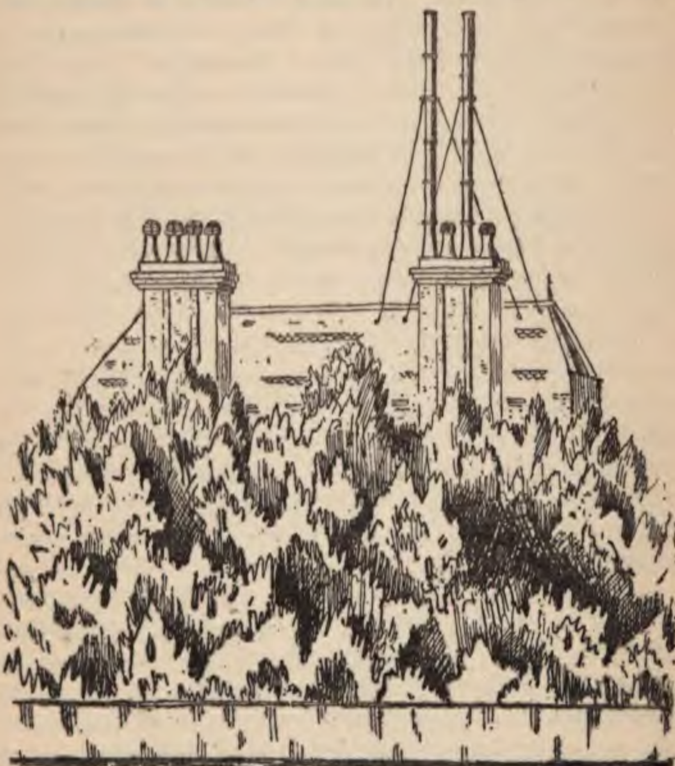

FIG. 12.—"Tall-boys" on a Residence.

might lead a person to infer that a chimney-pot will not warm a cold chimney, and that what is wanted is a grate that will. It may be an expensive item, but it will soon be found if cowls are tried that quite as much money will be quickly expended

without any satisfactory result being obtained. Then the coal bill with unsuitable grates is lamentable, and there is nothing like fixing a proper grate *at once.*

Much has been said about cold chimneys, so much so that the reader may conclude that if he will have a house built he will have none of them. The real cause and cure of these troublesome chimneys are so little known that it has been thought wise to thus treat the matter in detail, and when it is stated definitely that these cold chimneys are the bogies of villadom the wisdom of so dealing with the subject may be admitted. In order that the client for whom the house is to be built may know how such chimneys ought to be constructed so that they shall not give smoke trouble, the following remarks may be acceptable.

It is recommended that there should not be any projecting jamb on either side of the chimneys in the *outer wall,* because the action of the atmosphere will be upon a so much larger surface. Let the bricks be pressed if there are to be jambs, and sound, hard and of a dry nature in any case. It is most important that no sea-sand shall be used in the mortar, and let 30 per cent. at least of cement be mixed with the mortar in building the outside of these chimneys. Nine-inch brickwork with 50 per cent. cement and 50 per cent. mortar and fine sharp sand should be used wherever the slight additional expense is not an objection. See that the flues are carried up above the roof, and that chimney-pots which cause a drag upon the smoke and prevent down-blow are provided. Lastly, *and most particularly, see that grates suitable for such chimneys are fixed,* and then neither the architect nor the client need fear that there will be smoke trouble. Note the position of the ground, whether the winds will have much influence, and if there are to be flues in the outer walls against which the cold winds will strike with much violence, 9-inch brickwork is indispensable.

Having considered defective flues, defective chimney-pots will receive attention. It will be best to point out the physical

action of the wind upon them, because the general impressions upon the minds of those whose business it is to cure smoky chimneys are usually erroneous. It must be admitted, however, that these impressions were formed and fostered by the inventors of chimney-pots, who stated that their pots "induced up-currents in the chimney and prevented the wind blowing down". It has been stated already that the wind does not blow down chimneys unless they are immediately under walls or portions of other buildings against which the wind can cause the air to press with a greater force than that expelling the smoke in the chimney. The action of the wind upon chimneys in depressed areas and upon roofs above the fronts of houses upon which the wind impinged after leaving open spaces has been mentioned in the last chapter.

As the action of wind [1] upon chimneys generally was made the subject of experiment and research by the author, it may be referred to here more particularly. It has been long known that if the wind travels over the mouth of a pipe or tube open at both ends, much air is drawn out of the tube. This is in keeping with the law that moving bodies induce movement in those which they encounter, just as a billiard ball moves the one it strikes, and inventors of chimney-pots inferred that air behaved like the billiard ball, so that a wind blowing against the louvre ring of a wind-guard was not only deflected upward but caused the smoke to be sucked out at a greater rate. Fortunately for the chimney the physics of the inventor were at fault, because if the action of the wind upon the rings and vents of chimney-pots was to aspirate additional air to what was drawn out by the wind passing over the surface of the pot at these points, the mischievous effects of the invention would be potently manifest. The cowl and chimney-pot inventors never thought for a moment that too much air and smoke

[1] The results were communicated to the British Association at their Bradford Meeting in 1900 and proved by experiments with a large model.

was being drawn out of the chimney, as will be manifest to any one glancing over the specifications of these patents, which all claim increased aspiration as the result of the peculiar construction of the cowl. Nor did it strike them that air was elastic, that it could be drawn out and expanded like a thread of indiarubber, and that it would, like the rubber thread, snap back the instant the tension was released. This is just what happens when a strong wind is blowing over the top of a chimney, and there is a sudden lull in the blowing. If the room is small with little window space and the door and window are shut, the air supplying the fire has to come in through such small crevices that it meets with much friction. The top of the chimney being relatively large and the velocity of the moving air being more than three times, perhaps, that of the smoke in the chimney, the wind draws air and smoke out of the room underneath quicker than air can get in around the door and window to supply its place. A partial vacuum greater than usual is formed in the room, and when the wind ceases to blow for an instant the increased vacuum in the room must be satisfied. As air cannot get in through the crevices without encountering much friction, the smoke is drawn down the chimney to supply the place of the air sucked out, and thus a smoky chimney is formed. A good chimney-pot *is primarily a wind baffler, therefore, instead of a smoke aspirator*, but the inventor should aim to produce a pot which as the gust of wind ceased would tend to hold the smoke for a moment at the top of the chimney, so that some air can get into the room below before the down current begins to descend from the top. This is a great point in selecting a pot for a cold chimney.

A lobster-back cowl, if it were of permanent material and not subject to such intolerable noise, is an excellent cowl to give this final drag to the air before the snap back occurs, and allow time for some air to get into the room, so as to prevent the snap back occurring at all. Unfortunately, however, during gusty winds the battering of the lobster head is so erratic that

the mouth cannot be kept away from the wind, and the full force of the wind drives downward at intervals. All cowls and contrivances having tails to cause the wind to keep them in the required direction are open to the same objection, for gusty, choppy winds twist them round the compass. An ordinary pot without any baffle allows the wind to aspirate greatly and is the cause of many smoky chimneys. It may happen, and does in many cases, that the flue of one chimney carried up in a position which the wind sweeps over with freedom, draws so greatly upon the air in the house that other chimneys less favourably situated are much weakened and some smoke. The smoke curer immediately turns his attention to the weak or smoky ones, but a man who understands his business will prevent wind aspiration at the mouth of the exposed chimneys. A chimney-pot of the simplest form may be quite effective in some positions, and the best pot to baffle the wind may be less effective under the circumstances. For instance, if the ground is level and the tops of the houses are level, ordinary plain chimney-pots like Fig. 13 may be all that is required, as there are no smoky chimneys, the grates being reasonably suitable.

FIG. 13.—Common Chimney-pot.

It must not be forgotten, therefore, that such chimney-pots are the most useful under the circumstances, because as the wind blows over them more air is aspirated out of these pots than would be the case with a wind-guard, Fig. 14, with a pot having a cone top, Fig. 15, or, indeed, with nearly all the pots on the market. The houses referred to are generally low and occupied by artisans. When one has to deal with high chimneys such as are found in offices, flats, etc., then pots are required which prevent wind from aspirating, and which check the flow of air and smoke. For an exposed position on the top of a hill where the wind twists the lower air upwards, a pot is required which baffles the wind and at the same time does not allow the chimney to be unduly aspirated during the bouts

of upward wind suction. It is best in exposed situations to have good pots, but to avoid those which do not permit the wind to aspirate enough in moderately calm weather.

Every one will admit the benefit of having a chimney-pot which will draw air when the wind blows over it, as with a ventilator in the chimney-breast the vitiated air in a bedroom would be removed at a greater rate than if there were no wind suction, but a pot should be provided which, as before shown, will oppose the snap back mentioned above, else when a fire is lit in the bedroom it will be liable to smoke.

The kind of chimney-pot required depends therefore upon the situation where it is to be placed, and the selection of the

FIG. 14.—Wind-guard Chimney-pot.

FIG. 15.—Cone-topped Chimney-pot.

right pots should not depend upon chance or guess-work, but upon a knowledge of the physical conditions which are involved.

With regard to the defects in grates which cause smoky chimneys, the remarks made here will be general rather than particular, as the grates will be mentioned again when the heating is under consideration. A grate is defective when it allows too much cold air to ascend on either side of the flue over cold hobs, perhaps, or above the fire, owing to there being too much space between the top of the fire and the commencement of the chimney. Grates of this kind are very troublesome when fixed in small houses divided into two flats, especially when the flue is short or below the ridge of the main roof. A sheet of iron

hanging down 8 or 12 inches below the mantel in front helps to shorten the space above the fire, and if there are hobs, a sheet of iron, like Fig. 16, bent round to the back of the mantel, and with a hole just above the fire for the air and smoke to pass through, is the best provision. This with a good chimney-pot and a supply of air by means of a ventilator in the wall ought to prevent the smoke trouble. If smoke trouble is caused by an old pattern range which has no canopy to draw over the fire when it is open at the top, and there is simply a damper for the smoke to ascend through at the top of the range, an iron canopy arrangement fitted, like Fig. 17, just over the fire, as near to it as the kettle and saucepans will allow, is about all that can be done unless the chimney-stack can be raised or a

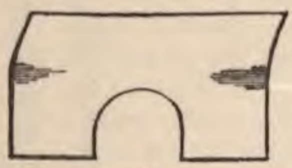

FIG. 16.—Sheet Iron to Close Opening above Grate.

FIG. 17.—Canopy for Old Cooking Stove.

6-foot chimney-pot erected. The canopy can be hinged at the top so as to allow it to be pushed to the back of the range out of the way. Fortunately this defect in such grates is rarely met with in new ranges, although not a few of these could be improved in this particular with advantage. Of the very numerous grates used for reception-rooms and bedrooms, those which waste their heat upon the walls beneath and smoulder so that little radiant heat is emitted, are quite unsuitable for cold chimneys, and for short chimneys in inner or outer walls. Grates which have sloping backs either of brick or of iron are not suitable for cold chimneys, which should have the fire right under the flue. The same remark applies to short chimneys generally, and to those on the upper floors in particular. Some of the grates have too much space for cold air at the sides or in

front, and may be benefited if these spaces can be curtailed.[1] The best cure is a good suitable grate provided with a valve arrangement for regulating the volume of air which shall get into the chimney-flue and which will do its difficult work in the case of cold chimneys with the least expenditure of fuel.

The last consideration is in relation to the defects in the room itself, which cause the chimney to smoke. These are two, and not unfrequently the two occur together, *viz.*, a very small room and insufficient air to feed the chimney. No matter how small a room is, the flue is made 9 × 9 inches because it cannot be constructed smaller, nor is it wise to try if the room has to be occupied by several persons. Rooms smaller than 12 feet square have rarely more than one window, and that is not of much size generally, and only one door. The air gaining access through the crevices around the door and window is very small, hence the air is forced in through the chinks and under the door at such a high velocity that the draughts are intolerable, so a mat is placed against the bottom of the door, indiarubber tubing is nailed on either side, and it is made as air-tight as possible. Because so little air gets into the room, the smoke ascends the chimney very slowly, and, as before mentioned, the soot is accordingly deposited in the most finely divided state, but cemented somewhat by the tarry matter when the chimney is in the inner walls. The chimney soon gets foul and smoke trouble begins. The remedy is to introduce air into the room partly close to the fire and partly so subdivided as not to cause much draught; a Sheringham valve behind a piece of modern tapestry or any other means of getting air which shall not be too apparent by its coldness. It is

[1] As an illustration of the unsuitable character of some modern grates, and that these give rise to smoke trouble, it may be mentioned that the author found on a recent visit to Sandringham that cowls and long tubes had been added to nearly half of the chimneys on the newer portion of the King's residence, with a view to stop the fires smoking, whilst the chimneys on the older portion of the building were not so disfigured.

almost impossible to ventilate such a room without draught if a fire is used, but if the chimney is not to smoke more air must be got in. If the flue is high a chimney-pot which prevents much wind suction is best for small rooms and a chimney-breast ventilator for use when enough air has been supplied for the fire to draw. Prevent the kitchen, if there is one close by, drawing upon the air in the house, and especially upon that which gets into the little room in question, and this is best done by giving a separate air supply to the kitchen itself. When the room is very small the skirting may be used to much subdivide the inlet air.

It may be in place to refer at this point to the dwelling-rooms which are built in our colleges for the occupation of the students. In Cambridge and Oxford the male students have usually a bedroom and sitting-room, the majority of which are of fair size. Those which are moderately large, and whose flues are not more than 9 × 9 inches do not smoke—enough air being provided; but those which are small and especially some of modern construction smoke badly. Some colleges for girls provide only one room which is used as a bed and sitting-room. In the case of one of these colleges by introducing fresh air, and the inlets being so situated as not to be subject to much air suction near the ground, good ventilation by care can be obtained, showing the possibility of making small rooms fairly comfortable. Another college for girls, in which two rooms are allocated to each student, but being badly placed as to wind suction upon the inlets, and the grates being faulty, the ventilation requires much watchfulness to make them habitable. Where a long corridor is on one side of a number of rooms, and the inlet air is supplied from that corridor, it should be warmed by hot-water pipes in the corridor before it gets into the rooms, and the air should be subdivided so as to give rise to a little friction and resistance, in order that choppy winds may not overturn the column of smoke in the chimney, especially if the chimney is short. This subdivision of the inlet air is

all the more necessary if the building is so situated that the prevailing winds cause much wind suction upon the windows of the corridor.

There is another defect which is found in some rooms, and which is often the last straw to break the force of the ventilating power of the chimney. It has been stated that the jerry-builder is not unfrequently the cause of making a cold chimney damp and colder than it need have been, and he is also responsible for having afforded the wind near the ground level the opportunity of adding this last straw. The woodwork of the house is bad and the windows rattle and clap in windy weather. Perhaps the cold chimney is in a dining-room having large windows, the spaces between the sashes and the frames are considerable, and the air supply through these sources is rather excessive. If the flue happened to be in the inner wall, it is probable that the window sashes would have had to be closed up on account of the draughts. Now it is a curious fact, but a fact notwithstanding, that by closing up the spaces somewhat between the sashes and frames of windows *when these are reasonably excessive*, there is very little loss of air getting into the room. The explanation is that the moment the air coming into a room is checked somewhat, the air ascending the chimney is heated to a higher temperature, so that the ventilating power is increased quickly with the result that more air is forced into the room through the spaces left. By increasing the ventilating power thus, the smoke in the chimney is not so easily returned, and in mild weather, if there is a liability to smoke trouble, one of the windows opened a little, not more than one inch, at the top will make up for any closing of the sashes. Now mark also how the wind outside will be baffled by this closing arrangement. The suction of the wind is always proportional to its velocity, and the resistance of the air to be drawn outwards instead of being forced through the crevices into the room will always be proportional to the velocity with which it travels through the chinks—hence the wind suction will

certainly be overcome to some extent, if not altogether, by closing the sashes which fit loosely. Care should be taken, however, that this closing is not overdone, and to consider what follows. Supposing the window sashes are very loose and that there is *no suction* of the wind upon them, although the flue in the dining-room smokes badly at times. The sashes are closed up, however, as recommended, to overcome wind suction at the ground level, with the effect that the fire smokes much worse: what is the matter? There is a door on one side leading to the kitchen, perhaps, and a serving hatch through the wall. When both of these are shut the dining-room fire is all right, but smokes when either is opened. Or it may be there is a fire in the drawing-room and billiard-room, and these rarefy the air in the house too much. The remedy in the case of the pull on the air from the kitchen is to be found in opening the kitchen window or the ventilator in it, and thus supply the air which the kitchen requires. In the latter case see that a bedroom window or a window on the stairs supplies air to feed the hall and the fires in the rooms leading from it. Unless reasonable common-sense is exercised, good chimneys will smoke for want of air.

A very frequent cause of smoky chimneys has not been mentioned yet, *viz.*, the accumulation of soot either throughout the length of the flue or most generally in the upper 10 feet thereof. Chimney stacks badly built facing the prevailing winds become damp, and the soot hardens and cakes, perhaps for a length of 10 feet or more near the upper end. If the sweep simply forces his brush up to the top without properly moving it back and fore to scrape away the soot, and this is damp, it simply forms a paste which hardens and contracts in dry weather. After some years the flue will be much constricted and begin to smoke very soon after it is swept. An instance came to the knowledge of the author in which the pasting up of layers of damp soot not only much constricted the flue near the top, but the louvre rings of the wind-guard-pot on the flue

were actually so plastered up with hard soot that the spaces between them became one solid mass. There are honest chimney-sweeps who do not scamp their work, and there are others who will get the best of one if it is possible. The author ordered a sweep to do ten chimneys and waited for him to turn up. Directly the author left, the sweep appeared, did two in some fashion and claimed for the ten. It is most essential, therefore, that the tenant, the tenant's wife or some trustworthy person watch the sweep at work, else it is probable that the upper portion of the flues will not be touched, with a view to his being sent for again before long.

There is no doubt whatever that the tendency of the housewife is to leave the chimneys unswept as long as possible, and if the flues are good this is especially the case. The reason is not to avoid the expense, of course, but to get rid of the nuisance and dirt which the sweep makes. A decent sweep will not make much mess, and when the tenant learns how important it is that the flues should be cleaned regularly and thoroughly, the objection will be overruled. In London where so much highly bituminous coal (Wallsend, Silkstone and the like) is consumed, the flues in every living-room should be swept at least *twice* a year. By living-room is meant that room in which a fire is lit every day in winter. If the drawing-room fire is lit only once or twice a week, once a year will do, although it should not be forgotten that more soot is deposited in a cold chimney than in a warm one. If the "draught" of a chimney in the inner wall is sluggish through some defect in the flue, much more soot will be deposited than in a chimney with a strong draught, and it will be wise to sweep the chimney every two months during fires. The largest quantity of soot and the bulkiest for its weight is deposited in cold chimneys in the outer walls, and if the chimney is very cold and the ventilating power very low, it should be swept at least once in two months, whilst an excessively bad example may be improved if swept every six weeks. The tenant of the house will, very

possibly, be glad to know that a suitable grate will much improve matters, but with the best grate the cold flue must be swept twice a year—the first time early in January and again after fires have been given up in May.

The tenants of houses having somewhat small living-rooms experience a close, heavy atmosphere in the spring-time, especially after the gas has been lit for a little while. This close and distressing feeling is not so much due to the heat as to the want of more air moving. If the chimney was swept, as too often occurs, in May of the previous year, some eleven months' deposit of soot has taken place, and the 9 × 9 inch flue is so constricted that the volume of air and smoke passing up is very small indeed. Had the flue been swept twice a year and the first time in January, considerably more room would be left for air to travel up the chimney in the spring months, and the room would be so much healthier to live in. Surely this last consideration ought to be enough inducement to have chimneys swept regularly; but do not forget that the ancient Briton who stood outside his house watching the advent of the sweep's brush through the top of the chimney-pot, not once only, but repeatedly, was a sensible fellow.

CHAPTER VII.

HEAT AND FUEL.

WHAT is heat?—"A mode of motion." When a gaseous body absorbs heat it is assumed that its molecules are moved farther asunder, and that their rapidity of motion is augmented. This increased velocity of the molecules is not heat, but the ether which pervades all space collects part of the energy of motion and sends it forward through its own mass in a series of waves or undulations commonly known as radiant heat, and travelling 186,000 miles per second. The energy of motion imparted to a body by heat does not become manifest in the ether as radiant heat until the atoms collide with one another or with the vessel containing the heated liquid or gas. The greater the force and rapidity of these impacts, the higher will be the pitch or intensity of the heat tone, the shorter will be the length of the waves or undulations, and the greater will be the distance that the radiant heat and light will be manifest from the body which gives rise to it. The mass of the sun consists of molecules moving with very high velocity, and the energy of their impact gives rise to vibrations which are visible to us as white light. As the radiations of heat and light pass through the outer envelope of gases and vapours surrounding the sun, more or less radiant energy having waves of greater length is formed, and these are carried forward by the shorter waves, and together enter our atmosphere practically unchanged and unabsorbed until the zone of perpetual snow is reached. Some, if not all, of the longer wave vibrations are absorbed by the air as radiant heat

after reaching the area of snow, and long before they get to the surface of the earth and sea. This conclusion is at variance with the information given in books on heating. Dr. Billings says: "Radiant heat . . . does not appreciably heat the air or gases through which it passes".[1] This hardly agrees, however, with the following: "The fire-place or open grate is the only one which really heats entirely by radiation, the greater part of the heat furnished by stoves and radiators being convected".[2] Dr. Reid said: "A common fire heats an apartment almost solely by radiation, excepting the influence of the flue upon the wall".[3] This statement is contradicted on the next page, where it is stated: "The great object with all ordinary fires is to heat the floor. If this be accomplished it moderates the severity of cold air there, and the upper portion of the apartment is warmed by the ascending currents that are immediately developed." Dr. Parkes said: "Radiant heat heats the body without heating the air". These statements have been made forgetting that radiant heat is emitted by bodies at all temperatures, and under the assumption that heat radiations vibrate at the same rate and that the waves are of equal length. Referring to what has been stated, heat rays which reach the surface of the earth appear to be almost entirely visible, and these pass through the air without being absorbed to much extent, but it must not be forgotten that the last particle of floating dust in the atmosphere which the sun's rays encountered before reaching the earth absorbed a little of the visible radiations and gave rise to some lower tones of heat. So far, therefore, the statement that radiant heat does not heat the air appears to be correct. This is only true in reference to *dry* air, but even then not altogether so, because there is no perfectly diathermanous[4] body. The mistakes made

[1] *Ventilation and Heating*, p. 212. [2] *Ibid.*, p. 213.

[3] *Illustrations of Ventilation*, p. 229.

[4] Substances which allow radiations to pass through them are termed diathermanous, those which do not allow radiant heat to pass through them without being themselves heated are called athermanous.

in the passages quoted are chiefly due to a confusion of terms. All bodies radiate as well as the sun, but radiation is not heat, nor does radiant energy become heat, until it is absorbed or stopped in its progress. Clerk Maxwell points this out clearly. He says: "We shall see that the phrases radiation of heat and radiant heat are not quite scientifically correct, and must be used with caution. Heat is certainly communicated from one body to another by a process which we call radiation, which takes place in the region between the two bodies. We have no right, however, to speak of this process of radiation as heat. We have defined heat as it exists in hot bodies, and we have seen that all heat is of the same kind. But the radiation between bodies differs from heat as we have defined it—first, in not making the body hot through which it passes; second, in being of many different kinds."[1] The heat energy radiated from the sun which reaches the earth does not heat the air through which it passes most certainly, the heat energy which was radiated from the sun and entered the earth's atmosphere but was gradually absorbed before it reached the earth's surface *did* heat the air. The red, yellow and orange rays visible to the eye are absorbed very appreciably by moist air, and the aqueous vapour present in the atmosphere is generally sufficient to ensure that this result shall follow. But even in moist air white heat vibrations pass without being absorbed, intercepted or heating the medium greatly. The lower the actual temperature of the object emitting the rays, the more of them are absorbed by the air. It is well known that there are heat rays which are invisible and which the thermometer shows us are less intense than those which are visible. The heat radiations from a body above 100° F. are usually manifest to the sense of feeling, but this is only so because the temperature of the human body is nearly 100° F. It is probable that a temperature of 60° may feel warm to the fish. The absolute zero of temperature is below

[1] *Theory of Heat*, pp. 15, 16.

− 256° Centigrade, the lowest temperature actually reached. There the heat rays are either non-existent or incapable of absorption; but above the absolute zero they are both absorbed and radiated by and from bodies of different temperatures. A lump of ice, therefore, immersed in liquid hydrogen would be a powerful radiator. Some writers have shown by octaves or steps the number of vibrations due to sound, heat and light, and how the wave-lengths vary from many feet in the case of the lowest sound octave to $\frac{1}{60,000}$ of an inch in the middle violet of the visible spectrum.[1] What concerns the student of heating is the fact that between the 11th and 44th octaves there is a wide range of tones or rays of energy. It is assumed with reason that between the 15th and 30th octaves the rays of energy are electric. The thermopile shows us that

[1] "We find the G of the lowest octave is made by 49½ vibrations. If we call this the beginning of octave No. 1, the G at the beginning of octave No. 2 has 99 vibrations, No. 3 is produced by 198, No. 4 by 396, etc. The G at the beginning of the 10th octave is formed by 25,344, and the 11th by 50,688. But this rate is too rapid to make any impression on our ears, probably because each succeeding vibration reaches the drum of the ear before the one preceding it has had time to produce an effect. The result to the ear is silence, but the vibrations may go on all the same, doubling in number for each octave. When the beginning of the 20th octave is reached, the G will be formed by 25,952,256 vibrations per second. The 30th octave takes in round numbers 26,575,000,000 vibrations, the 40th 27,212,800,000,000, and the 44th required 435½ trillions at the beginning and 871,000,000,000,000 at the end, or the beginning of the 45th octave.

"The G at the beginning of the 44th octave makes its impression upon us through the sense of sight, giving the sensation of that colour which a metal takes on when heated to redness. If the heat be increased the colour of the metal will change to bright red, then yellow, and with intimations of greenish and bluish tinges finally become white. In passing through these phases of colour it has, in reality, passed through different states of vibration, the final white colour representing simultaneous vibrations of all the notes in the 44th octave, from G to G" (*The Dynamic Theory*, p. 382).

heat tones of so low a temperature as to be invisible to the eye and insensible to the thermometer are converted into electric energy. Again, the velocity of electricity and radiant heat is the same. There is, therefore, a great difficulty in determining where electricity ends and radiant heat begins; but, just as it is known that the wave-lengths of electricity are longest where the number of vibrations per second is least, and that electricity passes through the air and non-conductors generally inversely as the length of its waves, it is evident the behaviour of radiant heat and electricity is strikingly similar. Whether radiant heat covers a range so wide as from the 35th to the 45th octave is a question that will not be discussed, but somewhere between the 30th and the beginning of the 44th octave a large number of heat tones invisible to the eye occur. The visible tones, red, orange, yellow, green, blue, indigo and violet, cover scarcely one octave. The temperature of the first visible heat tone—dull red—is about 1,000° F., the temperature of a white hot body is about 2,500° F., and this may be regarded as the maximum temperature which occurs in an ordinary open fire, even in winter time. It is the heat tones between the temperatures of 60° and 1,000° F. which require chief attention, and it is in reference to the dark rays, as they are termed, that the conclusions regarding radiant heat generally, and particularly as far as they relate to the heating of our dwellings or public buildings, are seen to be erroneous. What are the dark rays and how are they formed? The dark rays are lower tones and, possibly, in some cases, lower octaves of the visible rays, but they are not usually formed directly from the visible rays themselves. The rays of the sun fall upon the earth's surface and are more or less readily absorbed according to the nature of the material. Metals are good absorbents, but polished surfaces reflect the heat rays as they do those of light, and, consequently, do not become so hot as those which are not polished. A dead black or a polished black surface absorbs both the visible and

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and light rays readily.[1] When the light rays are absorbed by black surfaces they are reduced to lower heat tones. The heat rays of the sun (all of which, it will be assumed, are visible) are absorbed, and they first appear as molecular energy—rearrangement of the molecules of matter in the case of solids or the greater velocity imparted to them in the case of gases—and this increase of energy at once shows itself in the vibrations formed in the ether. The heat tones absorbed from the sun are all included in the 44th octave, and are visible to the eye as white rays of light, and they are emitted from a body above 1,000° F., but the temperature of the absorbent body after being exposed to the direct rays of the sun may, probably, not exceed 100° F. This body—an iron gate, for instance—would at once begin to send out radiant heat, but neither the number of vibrations per second nor the wave-length of those vibrations would be the same as those which fell from the sun upon the gate. The vibrations per second would be much lower, and the length of the waves increased considerably. The radiations from a body 100° F. appear to pass but a short distance through the air, and, unlike the visible rays, they are easily absorbed. The distance at which the low tones of heat are felt from a body 100° F. is regulated partly by the *amplitude* of the vibrations. If the radiated waves are reinforced by others having the same length, so that the crest of the one wave corresponds with the crest of the other, the amplitude is increased, and these vibrations should be felt at a greater distance from the radiator. On the other hand, however, when one wave is passing and another of the same length is travelling with it having its crest coinciding with the hollow of the first, the amplitude is greatly decreased. It may be inferred, however, that the decreases exactly neutralise the increases in amplitude. Lamp black and black matter generally which absorb the lumi-

[1] The author has frequently noticed how the polished black iron base of the fender will burn the hand whilst the polished brass fire-irons can be held easily.

nous radiations so readily and so much better than white substances, are less potent in the case of dark rays, especially when the actual temperature of the hot body from which they radiate does not exceed 200° F. Indeed, white lead is one of the best absorbents of dark heat. The experiments of Professor Tyndall showed that moist air was capable of absorbing much dark heat, and repeated experiments by the author have indicated that when a considerable amount of moisture was present in the air it greatly hindered the radiations of heat from a bright red fire being effective at a distance of much more than 12 feet. The experiments of Melloni are very interesting, and show clearly that the dark rays are entirely absorbed by most substances which allow large amounts of visible heat rays to pass through them. These dark rays resemble the luminous ones in that they can be refracted and polarised.

The following are the above conclusions briefly summarised :—

1. A large proportion of the visible heat and light rays from the sun reach the surface of the earth, showing that the air does not readily intercept vibrations of the 44th octave, or the visible heat and light rays.

2. The visible rays of heat are emitted by matter in the sun at a temperature exceeding 1,000° F.

3. The visible rays are readily arrested and absorbed by most solid matter, and to a certain extent by all matter, but it is very rare in Great Britain that the temperature of the material which has been subjected to the direct rays of the sun exceeds 180° F.

4. A body at 180° F. sends out radiations corresponding in wave-length and rapidity of vibration to the temperature of 180° F., consequently the waves are of greater length, and the rate of vibration less than in those undulations which come to us from the sun. In the same way a radiator at 200° F. will emit undulations corresponding to 200° F., and a stove at 600° F. undulations corresponding with 600° F., whilst a clear fire

will send out radiations having wave-lengths and vibrations corresponding with some of those which reach us from the sun.

5. The radiations emitted by a body at a temperature of 1,000° or less are arrested by moist air somewhat readily, whilst the longer the wave and the less the number of vibrations per second the easier the radiations are stopped.

6. Bodies which emit radiations of a certain wave-length have a peculiar aptitude for absorbing radiations having similar wave-lengths.

It will not be difficult to show how these facts bear upon the heating of dwelling-houses. In the first place it is noted that writers on heating have concluded that radiant heat, whether from a fire or from the sun, is of the same pitch, and that there is no radiant heat, or very little, emitted by a stove, a radiator or any other hot body not showing visible heat. Another common and most misleading mistake made is to assume that the popular material for the back of grates, fireclay, emits radiant heat of the same pitch and intensity as the white heat of the fire. Many grates have high backs sloping forward and extending far above the top of the fire with a view to radiate heat into the room. Fireclay can only send out radiations corresponding to the temperature at which it is itself heated. The temperature of the sloping backs above the fire of most grates rarely exceeds 200° F., and the dark rays emitted by this substance are so readily absorbed by the air passing into the chimney that such contrivances are not of the slightest value unless it be to render a chimney liable to smoke. Again, the coal used for grates in London and most towns is highly bituminous, and soot is deposited upon the firebrick sloping back only to act as a non-conductor to keep in the low tones of heat. It has been shown already that the sun's rays can heat solid matter upon which they fall, and that this solid matter can emit other heat rays corresponding to the temperature to which it is heated. As this is so, it indicates that all solid matter heated to a higher temperature than the air in a room must heat some

air by what is usually termed *convection*, that is, by the ascent of the particles immediately in contact with the hot surface. The author has repeatedly observed from experiments with radiators that the air is heated by the direct rays also, and that much of the air so heated rises at once to the upper part of the room. The currents of air thus formed may rightly be called *convection currents*. It will be found that the temperature of the air 6 inches above the floor is appreciably higher than it is 3 inches above the floor, much higher at 12 inches than at 6 inches, and the temperature increases considerably as the ceiling is approached. All this can be noted when there is no furniture to heat by conduction or by emitting dark rays which are so readily absorbed, whilst the radiations striking the wall opposite heat it, and give rise to other dark radiations which warm the air in the immediate neighbourhood, and cause it to ascend towards the ceiling.

From numerous experiments the author has found that luminous heat radiating from the fire carries forward lower tones which are easily absorbed, whilst much of the shorter waves meet with so much resistance or become absorbed by dark surfaces that they are thus reduced to lower tones whose rays are always available to heat the air of the room. The statement that the radiant heat from a fire does not heat the air of a room is, therefore, inaccurate, because it does heat it greatly, and appreciably, even when the temperature of the outside air is high and below 32° F. If any one doubts this, let him check the volume of air going up the chimney on a very cold day when a bright hot fire is burning. A fine thread of silk is unspun and fixed to the outer edge of the mantel-shelf, when it will be found that the flow of hot air as it ascends causes the silk fibre to rise at[1] times vertically with its unattached end at

[1] The irregularity in the current of heated air rising above the mantel is always noticeable more or less in all rooms, and is due to the unequal pressure of the outside air at about the same level, to the wind blowing over the top of the chimney or to both.

the top. To make sure that all this great volume of air heated by the fire is not due to the fender, etc., these may be removed, and the place covered with a non-conductor of heat instead. Under these circumstances the volume of air does not appear to be greatly diminished.

Those who state that the fire is the only one which heats entirely by radiation are equally inaccurate. The fender, dogs and irons absorb much of the radiations from the fire, as also do the floor, walls, chairs and other articles of furniture, pottery and bric-a-brac in the room. All these simultaneously emit dark rays of radiant heat corresponding to the temperature at which they are heated. In this way the luminous rays are absorbed, and the heated surfaces cause the air immediately next to them to be warmed and rise upward. All these articles of furniture so heated warm by convection just as much as does the hot-water radiator or the stove. Again, those who infer that the air is warmed chiefly by stoves, hot-water pipes and all apparatus below a red heat because it comes in contact with the hot surface are not stating the facts. If this were so, the effect of stove heating would be so nauseous, and there would be such a smell of "burnt air," that they would be even less desirable or endurable than they are. The low tones of heat may not be perceived by the sense of feeling for more than from 2 to 5 feet from the stove, but a very large volume of air is heated directly by the dark rays which are absorbed, and this volume ascends by virtue of its lesser density without coming in contact with the heating surface of the stove at all. Stoves do heat, therefore, by radiation,[1] and one-half of the heat given off into a room by a hot stove is absorbed by the air as radiant heat, and is not obtained from surface contact with the metal. The lower the temperature of the dark rays the quicker they are absorbed and the less impression naturally they make upon the

[1] It must not be forgotten also that the air in our dwellings contains much floating particles of matter, and these particles intercept the undulations and impart the heat so formed to the molecules of air.

sense of feeling. The rays from a radiator at 150° F. would not be detected at times by the face or by the back of the hand, perhaps, at more than a foot from the surface, and sometimes not more than 9 inches from it. If the surface of the skin is cold, the rays are detected at a farther distance, whereas if the skin is hot and moist, the dark rays are scarcely noticeable at 6 inches from the radiator. Notwithstanding all this, however, a large amount of the heating effect of hot-water or steam pipes is due to the radiant heat evolved as well as to the surface contact of the air with hot-water pipe or radiator. When the radiator is heated to 200° or more, dark radiations may be felt at times for a distance of 18 inches, whilst any one who sits within 2 feet of the radiator for a while and remains perfectly still, will experience a very pleasant sensation of heat, such as cannot be observed in any other part of the room. The thermometer does not show that there is increased temperature at the point. The low tones appear to be accumulative, and though the hands may be cool, if not cold, when sitting in any other part of the room, they always become pleasantly warmed 2 feet from the radiator. These low tones travel to a greater distance than we think, probably, although their intensity is inversely as the square of the distance from the source of radiation.

The above conclusions furnish a clue by means of which it is possible to obtain comfort in living-rooms, even during severe weather. In the old farmhouse, with huge hobs and fire-place and its warped and ill-fitting window frames, the supply of air was great and ample. One could neither sit near the door nor near the window in winter weather, but there were generally two settles, one on either side of the fire, arranged at such an angle that the cold air in travelling to the fire could not pass over the feet of those who sat upon them, because the backs of these were continued *right down to the floor*. To sit upon a chair in front of such a fire in winter gave rise to intense heat in front and a feeling of cold water running down the back,

results very frequently experienced in the drawing-room of to-day when one sits on the thin-legged fragile furniture found in it. The ancient farmer did not know that the radiant heat would be partly absorbed by the polished wood at the back of the settle, and partly reflected by the hard, shiny surface. But he found that by placing a settle at a reasonable distance from the fire, not only could the grateful warmth of the radiant heat be felt in front, but even the back of the legs and feet were warmed most comfortably as well as the upper part of the body by the radiant heat and light rays absorbed and emitted, or reflected, from the back of the settle upon the clothes of those sitting there, in the same way as the rays of light are thrown back by a looking-glass. The black or dark clothing worn by the occupants absorb both the light and heat rays, and it is difficult to picture a more comfortable position or one more free from draughts and cold shivers. The modern craze for fresh air can be satisfied with some degree of comfort if the chairs in general use, open at the back for frigid air to strike against the legs and feet, are abandoned. The seats must have backs which rest upon the carpet or floor so closely as to exclude air. If the occupant suffers from cold feet or rheumatism in the legs and feet, the front of the seat at the back of the legs might have a surface of polished metal or else be blacked. In this way the legs will be warmed when the chair or settle is brought near a fire which emits luminous radiations, for some fires do not. There should be a narrow cushion support fixed for the small of the back to rest against, and which will cause the body to be thrown forward some two or more inches in front of the rest of the back of the chair. This back is best made of oak polished by rubbing, and high enough to shield the top of the head from the cold currents moving towards the fire, whilst the form of the chair should be semi-circular, or even greater than half a circle, in order to shield the sides of the body from the currents also. There is nothing more satisfactory than the settle, both for comfort and sociality, but our forefathers erred in having a back

made too perpendicular and not furnishing any support for the loins of the individual. For consumptives and those who advocate much fresh air, these chairs or settles are indispensable for winter use.

FUEL.—Artisans and the working classes, generally, perhaps, give little attention to the nature of the fuel they burn in their homes. It seems a great pity that the question of price is usually the only one considered, because if any housewife needs a very serviceable and good coal it is the one who lives in only one or two rooms, and who has to do all the cooking and washing for the family by the aid of a small grate such as is often used in a bedroom. It would be well if co-operative stores and philanthropists afforded the working-man more help in this direction, pointing out that the cheap article is usually "cheap and nasty". The difference in the price of some coals does not necessarily mean that one is dearer than the other. A coal which costs 20s. per ton and contains 4 per cent. of ash is not dearer than another sample at 18s. which looks equally good but contains 16 per cent. of ash. The majority of coal sold at from 15s. to 20s. per ton in London is so full of shale or so intermixed with fireclay that it not unfrequently contains 30 per cent. or even 40 per cent. of ash, and scarcely deserves the name of coal at all. Coals so charged with mineral matter cannot be detected by their appearance except by an expert. Some are of a dark grey colour approaching to black with no striking brightness, whilst others are not bright at all but dead black. Even if the coal possessed the black shining quality which gave rise to the soubriquet of "black diamond," it is no guarantee that on burning it white ash will not manifest its presence. Some of the dull black varieties on the other hand are coals of fine quality. As the consumer must pay for his experience, he will be wise if he carefully notes how much ash results from a day's consumption, and whether that ash is white or red. He will not purchase a coal which, like cannel, will flare and send off dense clouds of soot to fill the chimney and empty his pocket,

The poor man wants a strong coal, but not what is known in the mining districts as "dry coal," a variety which will only burn and keep burning as long as a large body of hot fire lasts. The working-man should have a coal which does not waste one-half in caking, and yet it must be a coal which will last long and keep alight although *only one piece is burning*. There are such coals on the market, but these would become rare if the middle classes did not waste their money upon those highly bituminous or "fat" coals as they are sometimes termed, which approach very nearly in quality to the cannel coals used for enriching coal-gas. By the time the dense black vapour and soot have been driven up the chimney nearly one-half the coal has been consumed; and, just when a strong coal begins to emit powerful luminous radiations of heat, the "fat" coal collapses, and is soon after consumed. Those coals chiefly found on the outcrops of coal-basins which fuse and evolve streams of gases through holes in the molten mass are not well suited to heat a room. The fire is cheerful to look at, but the coke thrown forward in front of the bars hinders the luminous radiations getting free vent. A coal the lumps of which do not change their shape much in burning is the best. Whilst the physical qualities mentioned are important it is equally necessary to have only a moderate proportion of ash, and that this ash shall not be white, light or flocculent, otherwise it will be easily blown about and cause much dust in the room. A coal with a small proportion of ash either of a light brown, a dark brown or reddish hue is satisfactory, and when the quantity is really small the consumer may know he has got good value for his money. A very dirty coal is dear at any price.

The consumption of coal in cooking ranges, no matter how perfect the grate appears to the eye, is considerable. For this purpose the coal should be strong and of a character approaching the steam coal variety rather than the "fat" coals. A clean, hard coal, the smoke from which is inclined to be blue rather than dense black, is the most suitable. Do not purchase those

which are cheap and contain much white ash, because such coals burn freely and are very expensive in the long run. The economy of coal in kitcheners is further mentioned under that head.

If one or more living-rooms have flues in the outer walls, procure a clean, good kitchen coal which will give a cheerful fire without blazing much, and use it for all the fires throughout the house. It will be cheapest and best, because the fire will be hotter, there will be less soot going up the chimney and less smoke coming down, and there will be more ventilation.

Most persons of small means have tried the brickettes or other forms of compressed fuel, often known as patent fuel. This material is usually made from the small coal obtained by screening, *i.e.*, allowing the coal as it is tipped from the truck to run over a screen which removes the dust and very small lumps. The coal is mixed with a small proportion of pitch, heated and compressed by machinery. There are some few brands which contain a reasonable proportion of mineral matter, but the consumer will be wise if he obtains a strong, clean coal instead, as most of the compressed fuels are very dirty so far as the ash is concerned, whilst many contain coal so "dry" that it is scarcely combustible in an ordinary fire.

Much has been said and written about anthracite, and it has often been represented as the perfect cure for the fog troubles in our large cities. It does not give off black smoke, and the blue reek emitted is not objectionable. There are, however, serious difficulties in the way of its general use. In the first place, the dancing, flaming, flickering fire is the cheerful fire, and once take away these qualities and the possibility of seeing visions, if not of dreaming dreams when one sits with his feet upon the fender gazing into the luminous craters, and all or nearly all the pleasure of a visible fire vanishes. An open fire of fine anthracite nuts is certainly better than any closed stove, whether it has a mica front to give one gleams

of the hot fire or not, and apart from the sentimental associations just mentioned, little fault can be found with this fuel, excepting perhaps the difficulty of getting the radiations to be emitted powerfully from a sufficient depth of surface to face the room. With regard to a closed stove on the slow combustion principle, the adoption of Welsh anthracite as fuel would prevent the generation of much sulphurous gases and their escape into the air, but the amount of carbonic oxide produced, and which may possibly be driven back in a room on account of faulty flues, would not be materially lessened whether anthracite or coke was used. It is possible, however, to get anthracite so accurately broken as to size and so free from ash or other impurities that it can be burned in a closed stove almost scientifically, so as to get the largest amount of heat from the smallest consumption of coal. There is a good stove on the market for burning anthracite in this way. Anthracite was tried and much recommended for fuel in the Health Exhibition held in London, and whilst it can be so used by the middle and upper classes, it has not been since adopted to any extent. For poor people it is not suitable, not only on account of its cost, but because they are not provided with grates adapted for burning anthracite. Futhermore, in addition to being very troublesome to light, it is very apt to go out unless it receives much attention, and it is very difficult indeed to get a good front face of bright fire to shoot out powerful radiations.

Once the cheerful open fire is sacrificed, and a slow combustion stove is adopted, it matters little what fuel is used provided the consumption can be properly regulated so as to get the best results. There is no fuel except anthracite so well adapted for use in these stoves if they have long iron flues above them, as coke, because no soot or pitchy material is driven off, but unfortunately the removal of clinker causes sulphurous gases to pervade the room. Even anthracite is not quite free from this, although the quantity is so small that it does not

matter much. There is no fuel, however, which varies so much in quality, in hardness or in freedom from ash as coke. The coke used domestically comes from the gas-works, and is the remnant from which the illuminating gas, oils and tar have been distilled or driven off by heat. The fine quality coke used in iron-works is specially made from coal which has been washed to free it from shale, etc. It frequently happens that coals which contain much mineral matter give off gas of high illuminating power when heated, and these are generally known as cannel coals. Many of these coals do not cake at all, but maintain their original shape somewhat, although splitting much along lines parallel to the cleavage of the seam in which they occurred. Such coke is almost worthless, and care should be taken that stuff of this kind is not mixed with the better coke. In many gas-works two kinds of coal are used. One like that just mentioned, the other, and that used in the greatest quantity, a coal which gives off gas of a poorer illuminating value. This coal cakes, *i.e.*, partly fuses into one mass, which is broken up by the water used to put the coke out after it has been drawn from the gas retort and by the men during the operation. If the coal was clean and there was little ash left after burning, the coke would not contain an unreasonable amount, although it would be increased, naturally, as practically all the ash would remain in the coke. If, therefore, the coal contained 5 per cent. of ash and the coke remaining was 65 per cent. of the whole, the coke would contain $\frac{5 \times 100}{65} = 7{\cdot}7$ per cent. of ash. This would be a first-rate coke. Some gas-works have adopted the water-gas process for adding to the volume produced. By this process a further quantity of the carbon is removed from the coke, leaving it porous and easily crushed. If 20 per cent. of the carbon had been removed by sending a current of steam over the coke, we should find that 7·7 per cent. of ash would be raised thus: $\frac{7{\cdot}7 \times 100}{80} = 9{\cdot}6$ per cent. The foregoing

figures represent a really first-class coke, and very few samples from gas-works contain less than 10 per cent. of ash. Avoid soft, friable, dull-looking cokes, as, although they keep alight well in mild weather, they generally clinker very badly and contain unreasonable proportions of ash. A good coke should be bright and metallic in appearance, hard, not easily crushed, and free from *many* visible red spots of oxide of iron, otherwise the ash will clinker badly, and form such a fused mass that it can only be detached and removed from the furnace with difficulty. Nearly all cokes will leave a fused ash if the furnace or stove is forced unreasonably, but if either is carefully attended, and the ash is cleaned out at regular intervals, very little clinker should be formed. The author had some difficulty in getting a coke suitable for use in a slow combustion stove of a hot-water apparatus, but after trying several kinds succeeded in obtaining a satisfactory article. Where a house is heated throughout by hot water, and coke is the fuel used, it is most essential that the latter shall be good and clean, otherwise the servants in charge will not be able to keep an even temperature. The author found after providing a good coke that the housemaid kept the temperature within two or three degrees for weeks together, and the whole arrangement requires far less attention than one ordinary fire. The only other fire in the house is in the kitchen which heats all the hot water for baths, etc., and there is none drawn from the hot-water apparatus.

The householder must not expect his gardener to know much about coke, although he will be more interested in the matter if his attention is called to the quantity and quality of ash which remains, in order that a suitable coke may be selected for hot-water apparatus in green-houses, etc. This question of a suitable coke for heating green-houses is much more important than most people think, both from the point of view of expense and the general well-being of the plants in the houses.

The following figures give the composition upon the dry

sample of good bituminous coal, good anthracite and good coke obtained from gas-works.

	Bituminous Coal.	Anthracite.	Coke
Carbon	80·8	88·9	85·5
Hydrogen	5·5	3·5	0·5
Oxygen	6·0	2·8	1·0
Nitrogen	1·2	0·8	
Sulphur	1·5	1·0	2·5
Ash	5·0	3·0	10·5
	100·0	100·0	100·0

CHAPTER VIII.

FIRE-GRATES, STOVES, ETC.

FIRE-GRATES.—It is generally admitted that the open fire is the least effective heater, as only one-third to one-eighth or even less of the coal yields its full measure of heat into the room. As pointed out already, the heating power of a fire depends upon the intensity of the radiations emitted, and the intensity of the radiations upon the surface of a clear red fire facing the room. It will be well if the builder as well as the tenant makes the last sentence an axiom, and that the efficiency of all grates should be judged by this standard. At the same time, however, it must not be forgotten that if a grate has no provision for restraining the undue and unnecessary volume of air which passes up high chimneys during very cold weather, the full benefit of the radiations will not be experienced, because the air which has absorbed the dark tones of heat given off by the front of the grate and by the fender, irons, etc., will pass up the chimney instead of rising in front of the mantel to warm the upper part of the room. If the velocity of the air passing up the chimney is greater than the velocity with which the warmed air near the fire will rise because of its lesser density, the hot air will be sucked into the current going into the chimney in preference to rising into the room to take part in its heating and ventilation. The old-fashioned register grate whose opening at the back was small and not situated so that the air swept immediately over the top of the fire, sent out radiations of great intensity when the velocity of the smoke in the chimney

was from 4 to 6 feet per second, whilst the volume of air rising in front of the mantel was great, provided the supply of air to the room was ample. The more modern grates, perhaps, may be better-looking, more artistic, but many of them lack the effectiveness of the best registers in their power to radiate. There was one fault about this grate which has been remedied in later forms, *viz.*, the want of a good fret to prevent the air passing under the bottom of the fire to consume the centre of the coal, whilst the width of the basket from the bars to the firebrick back was somewhat too great. The coal basket should not be more than 6 inches deep from front to back, inside measurement. The width of the basket will depend upon the size of the room. A good grate with 16-inch fire will do for a room 16 × 14 feet, and a good grate with 18-inch fire will do for a room 20 × 15 feet, unless the latter faces a cold situation and is much exposed. The height of the firebars, which should be vertical and very small, ought to be from 8 inches to 8½ inches, so as to be able to furnish a high face of red fire during cold weather.

Referring again to the slow combustion fret, there is no doubt this is the most effective improvement made in fire-grates in modern times. At the same time it is surprising how little the value of the fret in effective heating and saving coal is known or appreciated. A closely fitting fret is most valuable, and a wise tenant should stipulate that the living-rooms, at any rate, should be furnished with grates having suitable frets. In most houses where frets occur they are left open unless the lady regards the appearance of the hearth, and looks upon the open fret lying awkwardly across the hearth as offensive to good taste. It is full time that the advantage of the fret is acknowledged and understood. If the fire has burned very low, it may be advisable to open the fret a little unless there is a blower attached to the grate, when this can be used to effect the same purpose. If the fret is opened, *close* it as soon as the fire has burned up a little. The saving of coal by keeping the

fret closed, especially in cold weather, is from one-sixth to one-fourth, whilst the effective heat sent out into the room is often doubled.

The next point to a good fret is to have bars which will not intercept the radiations more than need be. There is a new form of basket recently placed on the market having cast-iron vertical bars sloping forward greatly, and so thick as to occupy three-quarters of the front of the fire. This fire is said to heat the room and not the chimney.[1] No firebars are so suitable as those with thin, vertical steel rods, and there are numerous grates on the market having such bars.

One would scarcely think that the above information respecting grates was for the most part advocated by Dr. Reid in 1844, and it will be instructive to quote his remarks upon the requirements of the common fire. He says: "The great points which require attention in the common fire, are:—

"1. Depth of fuel, from top to bottom, and—

"2. Breadth from side to side, to give an ample radiating surface.

"3. A Blower, to close the ingress of air above the fire, that it may kindle quickly, and burn powerfully when necessary.

"4. A Valve or damper, to reduce the draught when the combustion is too rapid.

"5. A Front, made of the lightest possible iron bars that may be considered lasting, and placed on the level of the floor, that the floor and feet may have the fullest benefit from the radiation. Placed at a higher position, it has, in some respects, the advan-

[1] It is to be hoped the statement is incorrect, otherwise the ventilation will suffer seriously. It is a misfortune that three-quarters of the heat of a coal fire goes up the chimney, but it would be a much greater misfortune if the room could not be ventilated. It is well to remember that the hotter the smoke column in the chimney the greater will be the ventilating pressure, and the larger the volume of air which can be expelled from the room. Under the circumstances, therefore, the heat which goes up the chimney is not all "wasted".

tage of throwing the heat in a different manner, but it never then affords the personal comfort which a low fire presents to those who may wish to be sensible of the influence of its rays—a practice which, although not to be recommended to pass into a habit, is too agreeable not to be resorted to when the system has been chilled. It is not, in general, sufficiently remembered that the great object with all ordinary fires is to heat the floor. If this be accomplished, it moderates the severity of cold air there, and the upper portion of the apartment is warmed by the ascending currents that are immediately developed.

"6. An ash-pit, with means for preventing the ingress of air below the fuel. Air should enter in front alone; the radiation is then powerful in front, and strikes forward. In many fires the radiation is most powerful below, and strikes downwards, where it is of no value."[1]

It will be noted that Dr. Reid mentions a blower. This possesses a special value for cold chimneys in outer walls, for in addition to making the fire burn quickly and powerfully it sends a hotter current of smoke and air up the chimney, causing the ventilating power to be greatly increased. It is a decided advantage to have such a provision if the chimneys are exposed to severe wind effects, but the blower should not be used injudiciously, because the consumption of coal will be greater. Dr. Reid mentions a valve or damper to reduce the draught when the combustion is too rapid. It has been pointed out in some detail how valuable such a valve is, not only to restrain the air going up the chimney so as to check the combustion, *but to facilitate the removal of the vitiated atmosphere near the ceiling by using a chimney-breast ventilator.* Furthermore, a grate having valves opening into the chimney in such a way that the heated gases can be made to shoot upward at a high velocity is the safest guarantee that the smoke cannot be drawn down into the room by the suction of the wind outside near the ground

[1] *Illustrations of Ventilation*, pp. 230-31.

upon windows and doors. The saving of coal which results from the intelligent use of a valve or valves in restraining too much air from passing up the chimney is such as would lead the housewife to become practised in the art did she but have the opportunity.

If all grates were so provided, it would be possible to place a reasonable limit on the height of the opening to the flue. The maximum height of that opening above the floor of the room is usually given as 2 feet, but in many grates it exceeds this, and is sometimes 2 feet 3 or 4 inches. Anything above 2 feet is objectionable. It has been urged that the higher the opening the more material will be exposed and heated to emit radiations, whilst the quantity of coal consumed will be proportionately less. It will be well to deal fully with this matter at once, because the saving in fuel is more apparent than real, whilst the fuller heating effect is for the most part imaginary. There is a very serious objection to such high-backed grates, *viz.*, that in moderately warm weather such as is experienced in autumn and spring the volume of air passing up the chimney is too small to ventilate the apartment, and if the fire is forced with a view to increase the velocity of the smoke column, the room becomes unbearably hot. Grates which are under rather than over 2 feet high up to the opening into the flue cause the air and smoke to be heated before it enters, and the front of the fire is maintained brighter, with the result that powerful radiations of heat pass into the room. When the fire is much below the top of the firebrick back and the latter slopes forward, the fire during three-quarters of the year burns dead and the front of the coal is covered with ash, the result being that the radiations are stopped by the ash and thrown back again upon the red coals behind, and the heat eventually goes up the chimney. In severe weather, grates with high sloping backs restrain the air going up the chimney by their height and formation and are not so wasteful, but they are very ineffectual during nine months of the year. Furthermore, by having valves

to restrain the air going up the chimney the same effects can be produced with a grate having an opening into the chimney at a lower level, and one which will ventilate a room well in mild weather. Other points in reference to these grates with high openings to the chimney and sloping backs have been mentioned already in this chapter, and experience in their use has shown that once the smoke has descended into a room it is extremely difficult for the chimney to recover itself on account of the back sloping forward.

Fires burning without a basket have come into some favour of late years. This is partly due to the highly effective and artistic arches and tiled hearths which have been turned out by manufacturers in the Potteries. Some of these fires are very ineffective, and wasteful in the extreme. In modern houses constructed by conscientious builders for men who can pay the price, it is possible that the woodwork is so well done that scarcely any air gets into a room. Such an apartment may be warmed by a fire giving out no visible radiations somewhat effectively in spring and autumn, but if the tenant expects 10,000 cubic feet of air to pass through the room and up the chimney it will be almost impossible to warm the room under the circumstances in cold weather. Why? it may be asked. 1. Because the fire does not conform to the axiom that the heating power of a fire depends upon the intensity of the radiations emitted. 2. The surface of clear fire facing the room is not proportional to the mass of the fuel. 3. The low situation of the fuel and its relation to the opening into the chimney do not permit the air to keep a bright, clear front to the fire. Any fire which does not fulfil the conditions demanded by physical science—conditions which are based upon laws (not opinions) invariable and exact—must be condemned on that account. Taking the average of the year round, in some cases as much as 90 per cent. of the fuel is lost in heating hearths, walls, etc., and in passing up the chimney without first giving comfort in the room. All fires like those just mentioned do not afford

sufficient ventilating pressure to enable them to cope with severe wind effects, consequently such grates smoke badly when attached to chimneys situated in outer walls. Their inefficiency is not confined to these positions, however, because the author has frequently found the same experience when such grates were connected to chimneys built in inner walls in cases where the wind effects were turbulent.

Grates with movable canopies which close the opening to the chimney are useful as pointed out already on page 56. Sloping backs should be avoided, and the height from the floor to the canopy should not be excessive. If the chimney is of low ventilating power and cold, the closing of the canopy may give rise to two currents in the flue and cause the fire to smoke. The large surface exposed at the ends and side of the canopy enables hot air to go up on one side and cold air and smoke to come down by the other side. Grates with movable canopies properly made to fulfil the requirements mentioned above would be suitable for flues in the inner walls where the wind effects were not too boisterous.

Another grate which commands attention is that on the principle advocated by Sir Douglas Galton, and one which sends warm air into a room. At first sight one might be inclined to believe that this grate was a panacea for all evils in the form of want of air and smoke trouble generally, but long experience and some extended trial and use have not made it a favourite. In the first place, if the house is built it is very difficult to bring in a supply of air to the grate, and expense will be an objection. In the second place, where it has been fixed originally, and the air ducts built in the house as it was constructed, it is found that the effects are not so perfect as one anticipated. When the weather is cold and the ventilating grid is open, the moment the fire gets low the cooling effect of the frigid air current coming in is very pronounced, and if the room is left for an hour or two under the circumstances it becomes very cold. If the ventilating grid is closed, there is a strange

accumulation of sulphurous gases, apparently, as the moment the grid is opened again the sulphurous smell is very noticeable. In an office provided with a Galton grate the occupant told the author that he never kept the grid shut on account of this sulphurous smell experienced on opening it after it had been closed and which may have been caused by smuts deposited in the air passage. This brings a thought into prominence respecting these grates. How careful one should be to make sure that every joint is perfect between the heater in the grate and the fresh air duct! Is it possible to prevent the gases from the fire passing through the walls of the heater? is another question which it is to be feared must be answered somewhat in the negative. Though all these possibilities may be risked, there is still another objection. The cooling effect of the cold air upon the back of the fire and flue cause the smoke and soot to be deposited in the chimney in an extremely light and friable form, the result being that it is very liable to fall and cause much mess. This cooling effect of the inlet air which is heated interferes with the production of intense radiations. Apart from all this, however, providing no deleterious gases are mixed with the fresh air supply, a grate of this kind would be very suitable for a small room to prevent draughts if the tenant would not mind giving it a little attention, and this is necessary if one wishes to get ventilation and comfort. If there is a swirl near the ground when the wind blows, or suction results, care should be taken to protect the fresh air supply to the grate, otherwise the air current may be checked and overheated or burnt air get into the room. It is advisable to keep the grating shut when equinoctial or choppy winds are blowing.

STOVES.—Heating by stoves is more economical than by any form of open grate, although the effects are neither so healthy nor so pleasant. In America, where stove warming was once so general, much of the heating power was got out of the stove by making the flue pipe do its share in heating the building. For this purpose it had to be carried up through

the rooms of the house. With a temperature not unfrequently many degrees below zero, the tenants were not so conservative about the quality of heat, provided the house was warmed. The same remarks are still true in reference to farmhouses and out-of-the-way places, but the rapidity with which stoves are disappearing in the larger cities shows very conclusively that they are not desirable for heating buildings. In this country the visible flaming fire is usually the evidence of grateful warmth and comfort. In America and cold countries it is a sign of crowding around the one spot where the face is hot and smarting, whilst cold shivers are experienced down the back, legs and feet. An open fire is absolutely incapable of warming when the weather is so cold. As stated already, however, once one relinquishes the open fire in this country, it is but a question of warmth afterwards, and the tenant will only ask for the healthiest and most effective form of heating, and that obtained from the use of stoves is neither one nor the other. By using anthracite or the best kind of steam coal in a stove the trouble of clinkers or of much sulphur is eliminated, and if one attempts to burn coke in a stove fixed in a living-room the removal of clinkers will give rise to such an intolerable stink of sulphur, and the gases will act so deleteriously upon silver, picture frames, etc., that the tenant must discard fuel of that description. If one stirs a fire in a grate to remove slag or even clinker, very little sulphur gets into the room, because the fire is directly under the opening into the chimney. With most stoves it is different and the fumes cannot be so easily removed. There are many stoves on the market which heat fresh air and send a current into the room, and there is no doubt that several of these have been brought to a high state of efficiency. To avoid the unsightliness of the iron flue when the stove has to be fixed in a large office and at some distance from the wall, the flue is made to pass under the floor and then up the ordinary chimney in the wall. The flue must have a door in it to remove soot, etc., and through this door

some extraneous heat has to be supplied in order to start the stove, and if this is once done the stove will draw satisfactorily if the flue is good and of sufficient height. Stoves with open fires are most liked, and, although they are very wasteful, there is less need to make the iron-work as hot as possible. To get a large heating effect from the coal consumed in a stove, it is essential that some, and if possible a long length, of the flue pipe shall be carried up where it can heat the air. The stove must not be covered with non-conducting material like glazed tiles, terra-cotta or enamel, else the black rays from the iron lining, if there is one, will be returned to the fire, absorbed by the heated gases, and only a very small percentage of the coal will be effective in heating the room. Suffice it to say that a good grate will heat much better at less cost. The cast-iron stove of the cylindrical type such as is frequently used to warm galvanised iron buildings, schools, etc., utilises much of the heat of the fuel and warms a building effectively, but the smell of burnt air, the strange dryness due partly to the gases which have escaped and the great tendency there is for sulphurous acid and carbonic oxide to find their way into the atmosphere which is heated, render these stoves very unfit for general use. The most effective stove is neither so economical nor so satisfactory for heating air as a well-planned hot-water apparatus. To get full heating power from a stove the coal or coke must be burnt by the slow combustion method. Excess of air must be avoided, the amount being very carefully regulated by a sliding door or one with hit-or-miss grating at the bottom of the stove. *Dampers at the top of the stove should be always discarded*, as any pressure within the stove will be sure to drive deleterious gases through the opening where the fuel is supplied. If the weather is cold, the stove must be made very hot, and not only is there much waste heat and air going up the flue, but the air heated by the stove rushes up to the top of the room, and either finds its way out at once without warming the building, or gives up much unnecessary heat in a part where it is least useful.

The fire of the hot-water stove being surrounded by water will give up so much heat that the gases escaping will be of a lower temperature than from the stove just mentioned, whilst the radiators or pipes conveying the water will expose a larger heating surface at a temperature considerably below that of the stove. Every stove should have a water vessel attached so that the steam evolved might counteract somewhat the unpleasant dryness of the air. Stoves of the kind mentioned have fallen out of favour in this country, and are never likely to be much used, except for temporary buildings, notwithstanding the excellent workmanship and design bestowed upon many of them. Some of the better kinds of ventilating stoves are still employed in large buildings, but there is no question that hot-water heating is both cheaper and much more reliable and healthy.

Ranges and cooking apparatus have been noticed on page 98 as liable to smoke if there is no canopy or hood immediately over the fire, or one which can be made to occupy such a position when the fire is not forced. As many of the new ranges on the market are still only half-provided in this particular, it is well to point out to intending purchasers that it is a most essential requirement. Nearly all modern ranges aim at providing some form of hood, either sliding forward over the fire, or capable of spreading out to more or less lie over the fire when it is open at the top. Experienced tenants generally know in a very practical way that ranges are most expensive luxuries and that the coal bill is always a large item. If a cook keeps the fire closed up and "roaring," the weight of coal consumed is easily doubled. Hence the main point with all ranges is to prevent unnecessary draught, and to this end *maintain an open fire whenever practicable.* It is to make this possible that a good hood is necessary, and the form of hood which a range has should be duly considered by the practical builder, who is going to fix it, after carefully noting how the *range stands in relation to the back door*, especially if that opens out from the kitchen. If the air pressure comes in at an oblique angle to the front of

a hood which opens out from the back of the range, it will be found that the range will smoke unless the flue is swept frequently and the chimney "draws" well. This question of wind pressure and draughts from doors is one which should receive attention, and makers of ranges and cookers might add to the efficiency of the hoods by providing additional means for bringing them out farther over the fire when required. There is no reason why a sheet-iron folding arrangement with a simple hinge might not be added to some of the present hoods, so that when the kettle is not on the fire there may be a more complete gathering up of the stray wreaths of smoke. The sweep should be called in three times a year if the range is used during the summer, and the flue is "sluggish". The makers of ranges would act wisely if they printed a section along the line of the back of the range as well as under the ovens showing where the flues are situated, upon their cards of instructions, because a new cook may not "know" a certain range, and if through ignorance one of the flues is allowed to become so blocked with soot that the fire smokes, the *range* gets a bad name instead of the *cook*. The tenant should become thoroughly acquainted with the flues of the kitchen range so as to be in a position to tell what is wrong, and thus save extra and unnecessary expense in sending for the chimney-sweep to do the work which the cook ought to have performed. Where much hot water is used for baths in the morning the damper of the flue under the boiler has to be kept full open. The fire consumes much coal when this flue is drawing hard, hence it is best to cut the air supply to the lowest point as soon as possible, so as to prevent the water boiling in the cistern and undue consumption of coal in the range. It is far better to let the flue under the boiler just "draw" a little all day than to force it for "washing up," etc., because the cook is so apt to forget to close it again, as the opening leading from the fire is not in a position to catch the eye.

CHAPTER IX.

HEATING AND LIGHTING DWELLINGS BY COAL-GAS, ACETYLENE, OILS, ETC.

COAL-GAS is probably used to a greater extent to-day for heating purposes than it has been hitherto. This is not so much because it is suitable for the purpose as it is that it is convenient. The increased consumption is not altogether in the direction of gas fires in rooms, although the larger number of houses now built having chimneys in the outer walls tend to the use of gas fires on the first and upper floors because the chimneys smoke so badly with coal fires owing to the former being cold and the grates so unsuitable. It has been mentioned already how unwise it is to use a gas fire in a room subjected to down-draughts in the chimney, and there is no doubt that gas fires *do not cure smoky chimneys.* If a chimney "draws" properly, a gas fire can be used in the grate, but only then with any degree of comfort and safety. The readiness with which the fire can be kindled and the room made more cheerful has led to the frequent use of gas fires in drawing-rooms. They cannot be recommended on account of their costliness, and also by reason of the small amount of heat which they radiate. If a gas fire is to be used, the opening into the flue above the grate should be much contracted, and a ventilator fixed in the chimney-breast having no valve or impediment to prevent the air entering freely. The top of the chimney should be reduced to six inches in diameter, and where the family is small and the wind effects in the chimney-top considerable, to only four inches,

so that the outgoing air may pass at sufficient velocity to prevent a back draught. Owing to the lesser heat of a gas fire, it frequently happens that there are two currents formed in the chimney, one up and the other down, but the contraction of the opening into the chimney, and the orifice at the chimney-top, will prevent the back pressure if the chimney is in an inner wall. When the flue is in an outer wall a gas fire is very unsuitable. 1. Because the heat is not enough to warm the flue sufficiently. 2. Because about one-half of ordinary coal-gas consists of hydrogen, and the other half contains a further quantity so condensed that if it were set free it would occupy a volume nearly equal to that of the coal-gas itself, as will be shown presently. As all this hydrogen forms water when consumed in air, the hot vapour condenses in the flue rendering it damp, and in this condition the cooling effects of the air outside upon the flue are greatly augmented. The following analysis [1] of ordinary coal-gas, sample 2, from 15 to 16 candle-power

	Composition per cent. by Volume.		
	No. 1.	No. 2.	No. 3.
Carbonic acid	2·49	0·18	0·13
Oxygen	0·33	0·17	0·31
Olefiant gas and gases of the olefiant series	8·95	4·16	4·41
Hydrogen	39·69	49·98	47·32
Marsh-gas	36·27	36·35	38·21
Carbonic oxide	9·33	6·24	7·79
Nitrogen	2·94	2·92	1·83
	100·00	100·00	100·00

[1] These figures are taken from *Coal, Mine-gases and Ventilation*, p. 208. No. 1 was a gas enriched with cannel-coal, supplied to South Kensington Museum, and No. 3 was an analysis of the coal-gas supplied by the Cardiff Gas Company.

supplied to the Royal College of Chemistry, South Kensington, analysed by the author, will give some idea of the large proportion of water formed during its combustion. Not only is the 49·98 of free hydrogen in No. 2 burnt to water, but the 36·35 per cent. of marsh-gas contains twice its own volume of free hydrogen. The gases of the olefiant series (the chief illuminating agents) may be said to contain four times their volume on an average. Adding these figures together, it is found that 100 volumes of coal-gas furnish about 140 volumes of hydrogen. With regard to the carbonic anhydride formed on combustion of the coal-gas, the carbonic oxide will remain the same in volume after being converted into carbonic anhydride, whilst the olefiant gases may be taken on the average to yield three times their volume of carbonic anhydride. The marsh-gas will form its own volume of carbonic anhydride on combustion. These three, together with the trace of free carbonic anhydride in the coal-gas, show that 100 volumes of coal-gas furnish 55 volumes of carbonic anhydride. As the above figures represent a sample of the usual coal-gas supplied to towns, it will be seen how very wide of the mark Dr. Parkes was in saying that "one cubic foot of coal-gas . . . produces on an average two cubic feet of carbonic dioxide".[1] The figures given by Dr. Parkes as representing an analysis of coal-gas show very little more than half a cubic foot of carbonic anhydride per cubic foot of coal-gas. To the credit of the gas companies be it said that what Dr. Parkes regarded as a fairly purified gas would be looked upon to-day as a very bad sample indeed.

From the above figures it will be seen that the combustion of coal-gas gives rise to a large volume of water vapour,[2] and that if this moisture passes into the room it renders the air specially susceptible to be cooled by all surfaces at a lower

[1] Parkes' *Practical Hygiene*, p. 144.

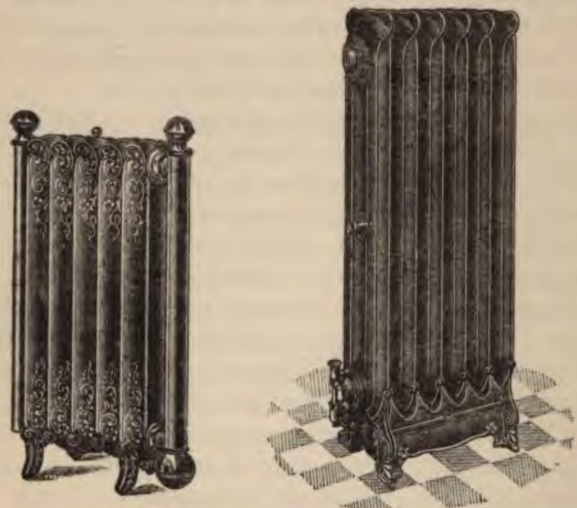
[2] The author has shown (*Ventilation and Heating of Churches and Public Buildings*, p. 47) that 1,000 cubic feet of coal-gas in burning saturate 100,000 cubic feet of air with moisture.

temperature. Just as moist air absorbs heat readily from warmer bodies, so does it give up heat readily to cooler bodies. When a room is warmed by naked flames of coal-gas some of the moisture is condensed upon the window glass and other cool surfaces which are at a low temperature in cold weather, the consequence being that so much heat is absorbed by cool damp surfaces that it is almost impossible to warm a room by naked flames when the air is below freezing point outside. It is because of the less volume of moisture evolved into the air that the condensing gas stove is so much more effective. The power of a gas stove to condense the liquid products of combustion depends upon the extent of the cooling surface over which the products move in the interior of the stove before they pass into the air of the room, and also upon the extent of the heating surface exposed to the air in the apartment to be heated. If the products wholly or in part pass from the stove without being made to descend to the lowest point possible for the gas to burn properly, the heating effects will not be complete nor will condensation take place as fully. It is most essential that a gas stove emitting its products into an apartment should condense as thoroughly as possible, because not only is the excess of moisture prevented from getting into the atmosphere, but the sulphurous and sulphuric acids also. There are several gas stoves on the condensing principle, and Fig. 18 has been used widely. The worst feature with most of them is that they do not condense enough moisture once they are fully hot, showing that they usually burn too much gas for the heating surface exposed.

FIG. 18.—Condensing Gas Stove.

A very effective arrangement is to heat a number of radiator sections or loops by gas. Figs. 19 and 20 show two forms of these radiators so heated. Such radiators furnish a very large heating surface giving off dry heat, and the single flame used

for heating need not consume more than $5\frac{1}{2}$ cubic feet per hour in the case of a heater with four loops. Some radiator stoves are fitted with a gas supply three times as great as is necessary to heat the radiator. This is done, perhaps, with a view to give some heating effect the moment the gas is lit. The wise consumer will purchase a radiator which uses the minimum amount of gas, and whenever it is wanted counteract the slow heating at first by having it lit an hour earlier, and thus most



FIGS. 19 and 20.—Radiators Heated by Gas.

certainly avoid not only extra expense but much unnecessary products of combustion in the room. The proportion of sulphur present in a room heated by one such burner is, of course, much less than that found where 20 to 50 cubic feet per hour are consumed. For offices these gas-heated radiators are cheap and effective in working, and fairly pleasant heating. If the products of combustion could be sent direct up a chimney the result would be still better. Stoves which heat asbestos films

to show a live fire in the middle of a room without either a chimney or a good condenser are not desirable.

Hood says: "All flame is next to useless for radiating purposes".[1] This is not altogether true, for when the flame is used to heat asbestos the radiating power is considerable. A naked coal-gas flame not only gives rise to much moisture, but that moisture absorbs the radiant heat which causes the air and gases formed to rise to the ceiling and will not readily diffuse downward. It is found, therefore, that the only effective way to use coal-gas is either to heat solid matter to a red heat so that it will radiate powerfully; otherwise, and best, heat a large body of water so that all the heat possible shall be got out of the gas consumed, the products escaping comparatively cool whilst the large surface of the radiator at not more than 150°, and better still at 100°, causes the air in the room to be much more evenly heated with the best results.

Where gas flames are used for heating asbestos fires, it is best to adopt air burners on the Bunsen type, but these should be so arranged that they can be dusted and cleaned. The old-fashioned Bunsens used in fires had two very unpleasant characteristics—the flame possessed a strong tendency to snap back, and light the jet at the bottom of the tube; and, by reason of the imperfect combustion which resulted on account of the insufficient air supply, intolerable stinking compounds were generated. Secondly, where the flame joined the upper edge of the tube of the burner traces of chemical compounds were formed giving rise to an unpleasant odour, and this is especially the case when iron tubes are employed. Under these circumstances, it is best to adopt a flame as it burns from an ordinary illuminating jet for heating purposes, where it can be used at a sufficient distance from the body to be heated to prevent the deposit of soot which occurs when a white gas flame touches a cold body.

[1] Hood on *Warming Buildings*, p. 521.

Bunsen burners have been much improved during recent years. It has been found that if the upper edge of a tube is reduced somewhat in diameter, the gas flame is not liable to recede into the tube; and it is also known that if the air gas flame leaves the top of the tube at a high enough velocity, the flame does not lie, so to speak, sufficiently close to the metal to cause much chemical action, and the peculiar smell is not so manifest. It was mentioned above that the air burners should be arranged so that they might be cleaned easily, as the deposit of dust upon the top of the tube gives rise to more chemical action and also more odour, whilst the settling of dust into the tubes hinders the gas rising with the maximum velocity which is necessary in order to get the minimum smell. It is very important, therefore, that air-gas burners and burners of the Bunsen type should be kept clean. This remark applies equally to the air-gas burners used in incandescent gas lamps with mantles, and it is a very salutary and sanitary proceeding to see that the tops of the common fish-tail and bat's-wing burners as well as those on the Argand type are kept free from dust.

Gas is used largely for heating water for bath purposes. When there is no boiler attached to a range there is nothing more effective than a geyser. Hot water can be got quickly and cheaply, too, if the geyser is sufficiently large—not less than $1\frac{1}{2}$ gallons per minute, and 2 gallons per minute is much more satisfactory. This means that 50 or more cubic feet per hour of gas will be consumed, and *it is imperative, therefore, that some provision is made to carry the products of combustion out of the bath-room.* If there is a chimney this will not be a difficult matter, *but even then it cannot be done effectually unless the opening to the chimney is completely closed excepting the tube from the geyser, and unless, too, the top of the chimney is considerably constricted*, i.e., *reduced to 4 inches in diameter.* Where there is no chimney in the bath-room, as is often the case, and the room is small, the fumes from the geyser are almost stifling,

necessitating that a tube shall be taken through the wall and perhaps carried up vertically for some distance. Whatever trouble is involved the products of combustion *must be taken away and not allowed to get into the room.* The gas jets usually employed for heating geysers are of the ordinary type used for lighting, and give white flames. These are best for the purpose. There are several geysers on the market fitted with arrangements to ensure the water being turned on before the gas is lit, and the purchaser will have no difficulty in selecting a reliable article. When the geyser is about to be used see that the quantity of water turned on is small, and it is advisable to heat it to a temperature of 150° F. or more for the first minute or two. The cold water supply can then be increased up to the capacity of the geyser. If the full supply of cold water is turned on before the gas is lit the condensation of moisture upon the metal in the interior of the geyser, due to the hydrogen in the gas, will be so great that the heating power will be greatly lessened, in some cases by more than one-half.

FIG. 21.—Gas Cooking Stove.

Gas is well suited for cooking, and there are several gas cookers on the market which are reliable. Fig. 21 is one of the best. The flames can be applied just at the points where they are most effective, and, considering the amount of heat necessary to keep the ovens and boilers going, the volume of gas consumed

is not excessive. There is much to be said in favour of a gas cooker for summer use, because the heat evolved is less than from a coal cooking range in actual operation, whilst the subsequent heating effect of the gas cooker after the gas has been extinguished is very trifling. The gas cooker, however, is far inferior to the coal fire range in winter. It is the kitchen which usually warms the house other than the living-rooms when there is neither a fire in the hall nor hot-water apparatus for heating; and it is a fact that where gas cookers are used in winter with a geyser for a hot bath, the hall and bedrooms are very cold and cheerless. Where there is a hot-water apparatus for heating the hall or a good fire or stove for the purpose the less heat from the use of a gas cooker is not so manifest, but if the servants sit in the room it will not be very comfortable in cold weather. Most of the gas-heated ovens on the market use the gas economically, but they should be provided with proper regulators which are self-acting. Some slow combustion stoves burning coke or coal are made to cut off the draught or fresh air supply when they get over-heated, but these regulators, whether pneumatic or electric, are not reliable enough. In the case of a stove or oven heated by gas, it is possible to regulate the temperature with great nicety, and it is a very decided advantage to have such ovens not only supplied with good thermometers but also with regulators which can be set to any required temperature. For instance, the cook requires the oven to be at a temperature of 300° F. As soon as the required temperature has been obtained, there should be a regulator which, having been set at 300° previously, cuts off a portion of the gas supply directly the temperature exceeds 300° F. An oven which possesses a regulator will enable the cook to roast a joint to a turn or cook pastry without blackening it. The best gas ovens are lined inside with a layer of asbestos board or slag wool. The latter substance has been found to give the better results, as shown by S. H. Davies, *Journal of the Soc. of Chem. Industry*, page 478, 1904. From these and other ex-

periments it is found possible to save nearly three-fourths of the loss of heat radiated from the iron oven uncovered with non-conducting material. The slag wool should not be less than one inch thick, and $1\frac{1}{2}$ inches would be better. The grilling, toasting and other arrangements in gas cookers have been brought to a high state of efficiency.

Gas is very convenient for lighting dwellings as it can be conveyed by pipes to any room. The first thing a new tenant should do who is going to use gas either for lighting only or for cooking also is to examine the condition of the pipes. This will appear at first thought difficult, because they are out of sight. The method is as follows. Having first become acquainted with the reading of the meter, note the numbers very carefully, placing them down one by one to be accurate. Give orders that all lights are to be out by eleven on a certain night and make sure this is the case, giving instructions that all taps are properly turned off. Do not cut off the supply at the meter, but let the pressure of the gas remain in the pipes throughout the house. The next evening make sure that the index of the meter is read before any gas is lit, and just note the difference between the reading taken the previous night. There should not be more than a foot of difference. Frequently there is much waste in the twenty-four hours, and the leakage has been so great in some instances as to form nearly half as much as is consumed during the four to seven hours of lighting at night. If there is a gas cooker, this must *not be used* during the trial, but the pressure of the gas should be upon the pipes right up to the taps of the cookers. It is not at all a bad method to take off the supply of the cooker close to the meter and immediately in front of this fix a good tap, then the pipes conveying the gas for lighting can be cut off during the daytime or at night by the tenant after the inmates have retired, and so save the waste when it is appreciable. If the tenant uses a gas pressure regulator, it is best fixed just between the meter and the supply, but the pressure must not be reduced too low if there is a

cooker, otherwise there will be a very unpleasant smell evolved and the full effect will not be obtained. Those who live upon a hill-side or at a considerable elevation above the gas-works should certainly provide themselves with a gas regulator on account of the extra pressure in the mains—not one costing £3 or £4, because they are not worth this price. One pound is enough for an effective article. If the tenant does not understand the action of the regulator, any plumber will fix it and point out how it works.

The burners usually employed for lighting by gas until recently were the fish-tail, bat's-wing and Argand. The two former were so named because of their resemblance. The fish-tail is the one generally employed when a globe is used, as the ends of the flame are not so liable to fracture it as is the case with the bat's-wing. Both burners, however, yield a light of poor illuminating power, and it is surprising that they are so frequently used now when incandescent burners with mantles are cheap and the light given by them is much greater. Where there is a strong draught and the light is subject to rough treatment, the bat's-wing and the fish-tail will be still used. In sitting-rooms which had three ordinary fish-tail burners, one incandescent burner consuming 4½ cubic feet per hour will give a light equivalent to the three ordinary burners consuming 5 cubic feet per hour each. The cost of mantles and renewal, as well as the first cost of the burner and chimney, have to be considered, but after all this has been duly weighed the value of the incandescent burner will be appreciated, and the cost will be considerably less provided there is no escape of gas from the pipes. The mantles should not be allowed to become perforated or very thin before they are renewed, as the great desideratum is to obtain the maximum light for the smallest consumption of gas. If the incandescent burners are subject to a draught, there is a distinct earthy, metallic smell given off which is neither pleasant nor desirable. The author has frequently noticed this in places of worship where the lamps were

fixed in the aisles, and there was a sweeping current of air from the door being opened frequently to admit the audience. The same smell can be noticed in a sitting-room which has its windows opened and the air pressure from the wind is variable. The smell and effect are probably the worst features of the incandescent gas burners. It is a distinct gain to have less heat and less moisture in the upper part of a sitting-room, hence the incandescent burner must be welcome on that account, but the value of the electric light is so vastly greater than this, and so much more sanitary, that any one who has used the latter for years feels that he cannot recommend the incandescent gas burner even when he has to pay 6d. per unit for his electricity. If the tenant has not contracted with the Gas Company to supply the mantles he can easily renew them himself without calling in a plumber, but it is certainly a convenience to the ordinary tenant to get both his gas and his mantles from the Gas Company who will undertake the double duty for him.

As it will be many years before the electric light will come into use in small towns and villages, the incandescent gas burner will hold its own for a long time, and it may be advisable to point out that as the intensity of all white light varies inversely as the square of the distance, it is best and cheapest to so distribute the burners as to fulfil the physical requirements. To this end, if two or three burners are used in a room, the modern practice of placing them against the walls is quite wrong in principle. In addition to the trying experience which the eyes undergo especially with incandescent burners when they are against the chimney-breast and one sits with his feet on the fender to read, there is a great loss of light in the centre of the room, and a dining-room table can never be made bright and cheerful without some additional illumination. For a dining-room it is always advisable to fix the lights in the centre and as far apart from each other as is possible under the circumstances. The author saw some incandescent burners with pretty opalescent shades so arranged as to throw the light downwards, but

the three burners in a group were within 6 inches of each other. In this case the radiated light and heat thrown back by the burners upon each other and reflected again and again, resulted in the conversion of much light into heat, and to a consequent great loss of illuminating power. The burners should be 2 feet apart in the central gasalier and as much farther as the design of the pendant will allow. If the room is not larger than 18 feet × 16 feet three incandescent burners fixed in the centre and burning 2½ feet each per hour will give a good light. If the dining-room is more than 20 feet but under 25 feet long, three burners consuming 4 feet per hour each will be ample for ordinary use, whilst one burner fixed at either end of the length can be used for festive occasions. It will not need much mathematical calculation to see that neither scientifically nor economically is it advisable to fix the burners for lighting *any room* in a dwelling against the walls. It is both cheaper and more effective to have a central gasalier in the drawing-room, whilst every care should be taken that no one is compelled to read with the intensely white light of the incandescent burner falling direct upon the eyes. As a further precaution the tenant will be well advised if he uses globes or chimneys which tone down the intense white glare of the incandescent burner. The ground-glass globe obscures 25 per cent. or more of the light. The opal shade, if fairly transparent, 40 per cent. of the light, whilst the thick, dense, opaque shades from 50 to 60 per cent. of the light. It is far better, therefore, to use a tinted shade as nearly transparent as possible for the purpose of toning down the white glare. A pink or a green shade—in fact any tinge of colour is preferable to the intense white glare, which is bound to injure the eyesight in the long run. This is a very important matter and should receive due attention.

Since the introduction of the incandescent burner the Argand has not been much used. The public are not familiar with this variety. It was formerly used in offices and public rooms, clubs, etc., but in such cases the electric light has now

supplanted the Argand. Those acquainted with condensing gas stoves know the Argand, as it is used in one of these which has been received by the public with favour.

A class of gas burner which appeared at one time likely to revolutionise lighting by gas had as its object the supply of air to the burner, and the subsequent removal of the products of combustion without their being allowed to get into the air of the room at all. This was a great step in the right direction, but it was very difficult to get the closed-in burners to work properly in awkward positions, whilst the light was not of high illuminating power for the quantity of gas consumed. The burner has been tried widely, but electricity is too formidable a rival for it to survive the competition. If the construction of a dwelling permitted the formation of a central tube or shaft running vertically from the centre of the ceiling on the ground floor, it would be possible to use a closed-up ventilating burner and get rid of the products of combustion altogether, but this is not practicable, and the electric light is much more desirable for new buildings.

Acetylene.—When this gas was first made on a commercial scale much hope was entertained that a really serviceable illuminant, which could be prepared very simply and readily from a solid material, had been discovered. No one anticipated that it would ever displace coal-gas, and it was not long before it was found that expense prohibited its use even to enrich the latter. Now that incandescent burners are so widely used to consume coal-gas, the intensity of the light produced is sufficient for lighting purposes generally, and on this score acetylene is no formidable rival. For railway carriages and factories where there is much vibration, mantles are not suitable, and in these cases acetylene is valuable, but providing there is an opportunity to generate electricity the electric light must have preference.[1]

[1] The writer was not a little surprised to find that acetylene, coal-gas, oils, etc., which gave a flame, were said to sterilise more air, and in this respect to be superior to electric lighting. Acetylene does not yield so

The question of illuminating dwellings is the only one under consideration, and it is to be feared that acetylene cannot be strongly recommended for the purpose. Where farmhouses, villas or larger dwellings in the country are concerned, the trouble of making and *purifying* acetylene gas are against its adoption, whilst it would, of course, be necessary to carry gas pipes throughout the house as if coal-gas were to be employed. For large houses and mansions the light is very brilliant, but if electricity can be provided it is very questionable whether acetylene can be produced so cheaply. Even if it is concluded that the question of cost is on the side of acetylene, it must still compete with water-gas, which is more free from impurity, and less destructive of valuable articles of *virtu,* as well as gold and other decorations. The objection urged against the use of air saturated with the vapour of gasoline, benzoline, etc., *viz.*, that it is not sufficiently strong smelling to be recognised if there is a leak, is not weighty enough, especially as it is possible to scent the gas and obviate this. The light emitted by acetylene is both powerful and pure, but a description of the installation of plant, either for the production of acetylene or of water-gas, does not come within the limits of this treatise.

In villages and country places the small householder cannot have even the advantage of gas, but has to be content with oil for lighting. That tenant, however, is not to be pitied, because a good oil lamp, even of the old duplex type, affords a nice light with little trying effects upon the eyes. It is not a good

much moisture on burning as coal-gas, but it contains its own volume of hydrogen, hence the illuminants which burn with flame give rise to much moisture, and on this account enable the bacteria in the air to multiply at an enormous rate, whilst the greater heat which results from flame illuminants adds much to the multiplication of the bacteria. Under the circumstances, therefore, what gain results from the sterilising of the flames is not equal to a tenth of the loss due to the multiplication of the bacteria, as the result of the extra moisture and heat formed by illuminants other than electric lamps. Furthermore, the incandescent light gives rise to a peculiar odour due, probably, to the imperfect combustion of organic material.

plan to have a low lamp, otherwise any one sitting before it feels the radiated heat very strongly. It is somewhat surprising that the ingenuity of the ladies has not been exercised in making a raised centre to a dining-room table of about a foot in height, so that the lamp or lamps can be installed on that eminence. A lamp three feet high looks lanky, but one of two feet raised upon a pedestal one foot in height will give a good light and the radiated heat will not be excessive. Much attention has been bestowed upon lamp shades, and especially for those lamps which have high stands resting upon the floor. The effects of silks of different colours and thickness will be referred to in detail in the next chapter when considering electric light shades, but the tenant who uses oil for illuminating purposes, and who surrounds the chimney of the burner with either a globe or a shade may profit if it is recognised that opaque shades should be discarded, and thick silk and highly coloured material tabooed because of the great loss of light.

The production of a first-rate reliable incandescent oil burner will be a boon to those who desire an intense light, but as oil is at present so cheap and the oil burners in use so effective, it is best to bear the ills we have and be content for a while. Do not buy cheap paraffin oil as it is dear at the price. It is a perfect nuisance to have to sit for hours with a paraffin smell pervading the room. The oils of high flashing point are free from smell and give a fine light. When judiciously used, the oil lamp, although it gives a little trouble, is cheaper than gas, and the products of combustion are less injurious. Oil lamps are to be preferred to gas, therefore, for lighting.

There are good geysers made to burn oil, and with care and cleanliness they are very effective. Oil cooking ranges are also receiving attention, and there is no reason why the farmer's wife should not have a most useful cooker for summer weather. Many of the oil stoves are capable of giving good results with a little care and attention. The wicks of these stoves should

be rubbed gently to remove the burnt carbon, and the reservoirs should be kept clean and free from extraneous oil. Oil stoves which do not smell are to be preferred to gas for heating bedrooms, halls, etc. The reservoirs of all oil lamps are now made of metal, and common-sense forbids glass or anything breakable. Even with this provision, however, every precaution should be taken, and care exercised to make sure that the screw plug of the reservoir is in position, and that the wick is not slack enough to allow oil to flow past or even inflammable vapour, else, if the lamp is overturned by accident, serious results may follow, because it is intensely difficult to extinguish paraffin once it is alight. Make a point of *trimming and filling oil lamps by daylight.*

CHAPTER X.

VENTILATING, HEATING AND LIGHTING BY ELECTRICITY.

WHERE the electric light is installed it is possible to use the current for ventilating purposes as well. In a small house or villa lit by electricity it is questionable whether it will pay the tenant to have a separate meter and wiring for driving a small fan which he will use in the summer to create a current of air in his living-room. The amount of electricity consumed by a 10-inch fan is so small and the number of hours when it is actually required in this climate so few that the fan may be driven from the ordinary current and fittings used for lighting. Small fans can be purchased cheaply, and if these are employed in a manner calculated to renew the atmosphere in the room as well as create a current they can be turned to useful purpose. It is well to remember that a current of air is borne best without giving rise to colds if it blows towards one's face, but it is not at all wise to sit in front of a fan. Some persons prefer to sit sideways, but when either position is selected it is quite possible that the air will be simply churned over and over without changing the atmosphere in the room. The oscillating fan gives rise to a very agreeable breeze, but it does not renew the air of the room appreciably. As a current producer it is superior to the fixed fan because the pressure upon the air is not exerted in only one direction, but varies at every point of the oscillatory radius. A much better plan is to make sure that the air is changed by the fan's action. Open the door of the room and the window farthest from the door. Open a

window or a door at the other side of the house with a free way through, and if there is a good breeze passing, the fan will not be required. Should the lie or construction of the house prevent a current of air moving naturally, one may be set up by making the fan face the open doorway and force air through it, or face the window and force air through that. In the former case the air so moved will be partly replenished from

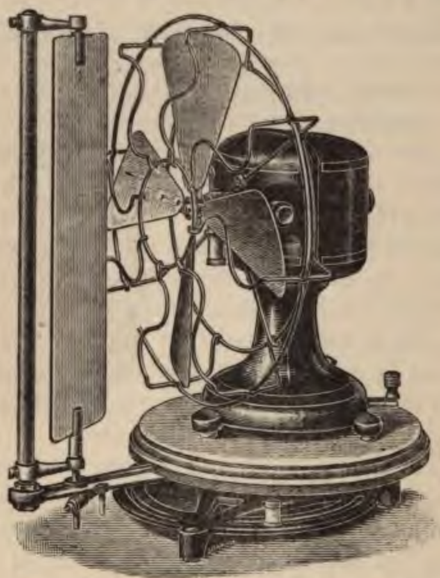


FIG. 22.—Electric Fan with Oscillating Base.

the window, and any one sitting near can experience a most refreshing breeze. The strength of the breeze can be regulated both by the rate at which the fan moves and by the distance the fan is fixed from the doorway. This is the best method of using a small fan. It need hardly be mentioned that the fan should be switched off when the occupants leave the room, or the moment it is not required. By carefully doing this in the

case of the lamps also it is surprising how the electric light account is lessened.

In those cases where the tenant uses electric heaters or cookers and expense is subservient to comfort, the electric fan can take the place of the heater in summer, and a breeze be obtained in the bedroom as well as in the living-room. To obtain the current of air it is much better to cause the fan to blow away from the bed towards the window than to simply give rise to a current moving direct against the head of the bed. The fan should stand 2 feet above the bed and close to the bottom rail. If there is a doorway leading through the wall against which the bed is placed, it is possible to create a current by blowing slantwise through the door. A little ingenuity will enable the occupant to use the fan both for ventilating and refreshing purposes. Fig. 22 shows one of the fans used for the table, and which can be placed so as to obtain the currents mentioned. It has four speeds, and a regulator switch. It is shown in the figure standing upon an oscillating base which makes it an oscillating fan. By taking the fan off the base it can be employed to drive air out of a door or window or in any one direction as mentioned above. Fig. 23 shows an electric fan held in a frame. Fans arranged in frames for fixing against walls can be employed in large rooms, if required, but they are seldom necessary in private dwellings, except in the case of w.c.'s, where they are valuable. In the latter case one speed only is required, and a 10-inch fan is quite large enough for a single w.c.

FIG. 23.—Electric Fan in Frame.

For summer use the value of the *punkah* is not fully understood. The temperature is so variable in this country that cool breezes are not appreciated in the same measure as they

are in India, and the possibility of obtaining a breeze naturally is another reason why the punkah is not so much sought after. When doors and windows are kept open in a room in hot weather a punkah not only gives a movement to the air which is refreshing, but causes a considerable change of atmosphere. If electricity is used to gently move a punkah of considerable size, no greater effect can be accomplished for the expenditure of so small a power. The refreshing character of a breeze is proportional to the irregularity of the pressure rather than to the steady and continuous current.

It will probably be a long time before heating by the electric current will be much adopted. Not that electric heating is undesirable, because we cannot conceive anything more sanitary, or more readily adjustable to the variable temperatures experienced in this country. The next best method of heating, by hot water, is alike free from deleterious products, but it is less easily and rapidly adapted to the circumstances of a rising thermometer, and for supplying just a very small amount of heat when required. Whilst, however, electric heating in dwellings is so desirable for temperatures above 50° F., the apparatus for the purpose is both expensive to buy and costly to maintain. An electric heater with four lamps consuming two units of electricity per hour will heat a room 16 × 14 feet having a register open, when the temperature of the air outside is 50° F. This means 4d. per hour with electricity at 2d. per unit—an expensive luxury if used for ten hours per day. When the temperature outside is at or below freezing point, the electric heater with four lamps is of little value, as the heat evolved is so inadequate. The author was surprised at the great ingenuity of the vendors of one such heater, who tried to give him a learned dissertation upon the unique character of the radiant heat which was given off by the electric tubes. This was likened to the radiations from the sun, and it was alleged that there were no radiations like these emanated in any other form of heating. When asked what all this

dissertation was for, they politely informed him that the short lecture was given for the purpose of allowing the radiant heat to warm the body, so that the warmth evolved might be appreciated. It is well to warn the purchaser that the radiant heat from the glow-tube radiator is like all radiant heat of the same intensity, and that what the vendor stated was not correct.

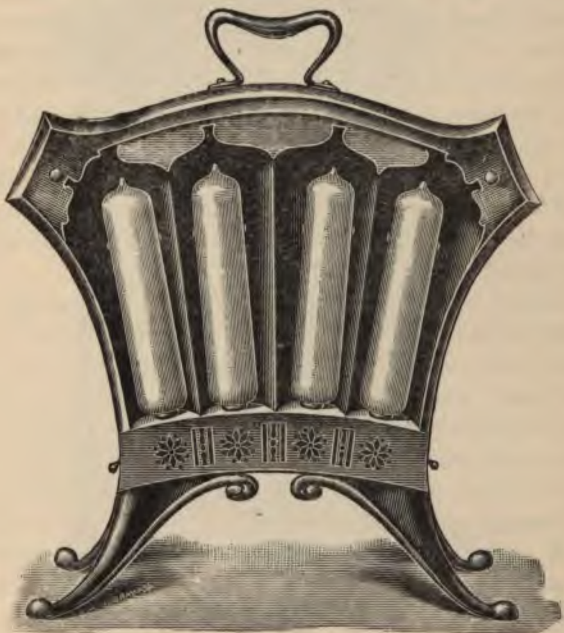


FIG. 24.—Glow-lamp Radiator.

The radiations emitted by a fire are of the same kind and quality. Such radiations are healthy and desirable, but at present they are very dear at the price. Those who have the electric light installed will find an electric heater, like Fig. 24, excellent for warming a bedroom. Unfortunately for the consumer it is necessary to-day to have two meters where electricity is used

for heating as well as lighting, and it involves also two separate services of wire throughout the main portion of the house. This, of course, adds to the expense and makes electric heating less likely to become general. The electric heater does not contaminate the air of a room, and on this account, if the latter is not occupied at the time, every window, door, register, chimney-breast ventilator and all inlets and outlets should be carefully closed, so that the radiations from the heater shall warm the walls as much as possible, and prevent the warmed air from escaping. When the occupants enter, if only two or three, the chimney-breast ventilator should be opened just a little, whilst, should the register close badly, it ought to be packed with canvas or other material to make it as air-tight as possible. By a little scheming of this kind the heating power of the electric tubes can be turned to the best account, and the expense will not be so apparent.

Electric radiators having glow tubes like Fig. 24 are being adopted somewhat widely for heating living-rooms in flats and houses, also city offices. When the electricity bill comes to hand after a winter quarter it is probable the amount will be greater than the tenant expected, and the vendors of the electric current ought to reduce the price by one-half in order to make electric heating more practicable. A number of electric glow tubes can be made up so as to form a large battery for heating the air supply, and this has been done already to some dining- and smoking-rooms in hotels and clubs. As these heaters can be switched on or off as required, they need only be at work just at the necessary time during *mild* weather. In severe weather, however, the heating must be commenced some time before the room is occupied, otherwise, owing to the walls being cold, the incoming air will lose its heat and descend in a most unpleasant fashion. The heated air has to be driven into the room, perhaps, through the cornice on one side and out of the cornice on the other side, assisted, it may be, by another fan which aspirates upon the outlets. In one or two instances the

air has been washed and ozonised, but in dwellings such precautions will rarely be adopted. As the air supply generally leaks into an apartment around window sashes and doors, it would not be easy to ozonify the air as it entered through the inlets, but the air in the room could be electrified if it was desirable. It does not seem, however, from present knowledge,

FIG. 25.—Electric Convector.

that any benefit would accrue, whilst it is not at all certain that ill results would not follow.

There are other electric heaters on the market besides those having large lamps or glow tubes. Figs. 25 and 26 represent two of the best. Some persons object to electric heaters of these patterns because they do not emit their maximum temperature for some time after the current is turned on. This is the case with the glow-tube radiator but not to the same extent.

In radiators like Figs. 25 and 26 practically all the electricity is converted into heat and there is no loss, but in using radiators of this kind it is best to work them at half power, and employ two instead of one, so as to get more heating surface. All radiators should be constructed to present the heating surface to the air, so that the latter can escape into the rising current the moment it has touched the heated surface. Heaters of the horizontal pattern used upon passenger steamers are well adapted for the purpose, especially those having holes through them like a ventilating grid.

FIG. 26.—Screen-like Electric Radiator.

As will be shown in chapters xi. and xii., the economical heating power of a radiator depends greatly upon the exposure of a large surface at a comparatively low temperature, and the manufacturer of electric heaters will act wisely if he keeps this fact in mind. The great point in electric, as in all heating, is to warm the air at the floor level, so that the temperature there shall not be many degrees lower than it is near the ceiling, and in order that this may be done the heater should be low and long.

Electric ovens and cookers have been tried, but the cost of the electric current is prohibitive. The price charged for these ovens must be necessarily high, and, as in the case of other electric heaters, it is to be regretted that the cost of the current

makes what would be otherwise a great boon to the public prohibitive and regarded at present as a luxury. It is quite possible for manufacturers to construct compact ovens protected by good non-conducting material, so that practically all the heat generated shall be used up for the purpose in view. On account of the great waste of fuel in coal ranges when they are forced for cooking, it would be quite possible for electricity to compete with a coal cooking range, and not be more costly, provided the current producer sold it at a small margin above the expense of production. As the electric cooker will not heat the kitchen nor the house much in summer, the tenant might pay a little extra for the benefit. In using electricity for heating it is quite possible to make the most of it in all operations and to

FIG. 27.—Electric Curler.

apply it just at the points where it would give the highest results. The misfortune is that the actual quantity is so small. It has been mentioned already that heat from electricity is always obtained by subjecting the latter to great resistance. The current tries to overcome this resistance, and in the struggle electricity is converted into heat, and if the heat is intense enough light results. This is the case in the Swan lamp, it is the case in the electric glow-tube heater, it is the case in the copper strip as well as in the platinum foil heaters for cookers and boilers. The electric heaters for ironing hats and clothes, for warming hair curlers, Fig. 27, etc., act on the same resistance principle; it is only a question of the different material used to "resist". There is an electric grill, an electric kettle, Fig. 28, an electric

flat-iron, Fig. 29, an electric plate-warmer, etc., on the market, and these are very nice and serviceable—the first cost and subsequent expense in working being the only drawbacks.

Some idea of the cost of electricity for heating purposes would be acceptable, but there are many difficulties in estimating this. If we compare heating by hot water with heating by electricity, it may be taken as approximately certain that the cost of the latter is at least thirty times as much. To compare electricity with a coal fire for heating is not an easy matter, because, besides the effective heat thrown off into the room by the fire, some account must be taken of the ventilating force which the heat escaping up the chimney produces. Under the cir-

FIG. 28.—Electric Kettle.

FIG. 29.—Electric Flat-iron.

cumstances, however, one cannot say that heating by electricity is less than ten times as costly as a coal fire. The difference between the cost of heating by gas and by electricity, when the ovens are carefully protected by non-conducting material, would be from two to four times in favour of gas according to the price charged for gas and for the electric current. These estimates are based upon a charge of 2d. per Board of Trade unit for the electricity used for heating.

Electricity is, undoubtedly, the power of the future as well as the medium for heat and light. A really up-to-date house would not be complete without electric lifts from the kitchen, and some are provided with passenger lifts even to the rooms

above, but there is no question that the electric light should be installed in all new houses if the current can be obtained. One might go as far as to state, too, that should the tenant require to supplement the coal cooking range for the summer time or part of it, and there was no gas in the house, an electric cooker could be installed. Or an oil cooker could be employed, and this would be easily manageable in suburban villas and all dwellings which had a reasonable place for storing a gallon of oil. There was a time when it was thought to be unsafe to dispense with the gas burner for fear the electric current should fail, but that time has passed, and if an accident should happen it is not difficult, when a little oil is at hand, to supply a light for a few minutes, or a few candles will tide over the difficulty.

Some people dread having gas in their houses, and the above remarks are made to assure such that if the electric light has been installed the objection to the use of the coal range in summer can be overcome without much difficulty by using oil, if the extra cost of an electric cooker is an insuperable objection.

Whatever difficulties may be in the way of using electricity for warming rooms or for cooking purposes, no such hindrances occur in the employment of electricity for lighting. The electric light as used most generally now in dwellings is obtained from a carbon filament fixed inside a glass globe in which there is nearly a perfect vacuum. This carbon filament is rendered incandescent by the electric current for the reason already explained. The copper wires of the electric currents are very good conductors of electricity, and a powerful current will travel along a small wire even without giving rise to an appreciable amount of heat. This shows that the electricity does not encounter much friction or meet with much resistance in its passage along a copper wire, but when that same current comes in contact with a thin carbon filament it passes along with extreme difficulty, and meets with so much resistance that the electric current is converted into heat, and the carbon is made white hot in consequence and gives light. A pure carbon fila-

ment gives a white glare which, like the incandescent mantle of the gas burner, is very trying to the eye. By adding a trace of common salt to the carbon filament or the material from which it is made, the white glare is removed from the lamp, and the eye can stand the slightly yellow light without injury. The one drawback to the use of a clear glass globe is that the filament in either an eight or sixteen candle-power vacuous tube is so very thread-like in size that the incandescent carbon is somewhat trying to the eye. This can be overcome and the filament obscured by grinding the outside of the glass globe, but there is a loss of 25 per cent. of the light in so doing. If the lights in a room are fixed upon a central electrolier and are at the back of the person who faces the fire-place when reading, clear glass lamps can be used, and the filament will not be manifest to the eyes if the electrolier is raised a foot or two above the head of the reader. Or a shade can surround the lamps, so that if necessary the light can be lowered within a foot of the book that is being read, of the writing or other work which is being done. If money is no object, the tenant may place his lamps where he likes, and as many of them as he pleases. Those who desire to ensure the porosity of the ceilings to air and keep them white may have an elaborate design worked out in plaster more or less raised to be effective and finished off dead white. In this case the electric lamps can be fixed close to the ceiling without fittings which will cast shadows, and the apartment lit by the diffused light reflected from above. This is a costly way of lighting, but it is a very pleasant and effective method notwithstanding, whilst for the eyes it is certainly the most restful of all. Reflected light from the ceiling is not more expensive than what might be termed the Chinese lantern or pantomimic method of lighting living-rooms. This is regarded as something *chic* by the ordinary plumber who has developed into an electrical engineer with the advent of electric wiring and lighting of houses, and consists of a number of single lights fixed to brackets on the walls, the lights being

covered with coloured shades which imitate petals and flowers. From the centre there may hang a cumbrous electrolier having some lamps near the ceiling to light it, and other lamps nearer the floor to light the lower part of the room. These lower lights are surrounded with a thick red or yellow silk shade, rendering them of small illuminating value. The writer has seen many such rooms, small and large, having six to twenty lamps or more, and one such room not larger than 18 × 15 feet with ten lamps had shades of dense cardinal red material, the effect of which reminded one of the red glare produced by burning a strontium compound in a pantomime. The ten lamps did not give a light of as much intensity as four clear lamps without a shade would have done, whilst the theatrical results produced were as devoid of good taste as they were wasteful and costly. Many tenants of small flats or villas pay from £15 to £20 per annum for their electric light, and when these are asked what electricity costs it is at once and naturally set down as an expensive item, if not a luxury. In some cases rooms are lit from brackets on the walls without a central electrolier, the centre of the room being illuminated by a number of single lamps suspended from the ceiling at a distance of 4 feet perhaps from the walls. It is certainly cheaper to light a room by bringing the lamps within 6 or 7 feet of the floor than to hang them higher up, and as electric lighting adapts itself more easily and economically to ready distribution of the lamps so as to fulfil the physical conditions necessary to secure a uniform lighting effect, this consideration is well worth a little further inquiry. The quantity of light which any surface in a room receives from a lamp will vary inversely as the square of the distance from that lamp. In other words, if a lamp is held by a bracket close to a wall, and at one foot distance the light is equal to eight candles, the illuminating power will not be equal to four candles at 2 feet or twice the distance, but only two candles. The reason of this is simply because the rays have dispersed so as to cover four times the same area. When the lamps are fixed close to walls, and the

room is, for example, $15\frac{1}{2}$ feet wide, there would be a distance of 7 feet from the lamps on either side to the centre of the room. The rays of light in their dispersion would fall upon a surface thirty-six times as large in the centre of the room as they did at one foot from the lamp in question. It is not necessary to complicate the matter under consideration by noting how the rays from one lamp cross those from another and so on, suffice it to say that the illuminating power would be greatly reduced in the centre of the room. If the walls of a room were painted or papered dead white, much of the light which fell upon them from the lamps close by would be reflected back into the apartment, and add to the illuminating power, but the tenant will not tolerate dead white, cold-looking walls in living-rooms, and it is certain that the papers and decorations used to-day absorb the greater part of the light, the strong light falling upon them, and there is much loss resulting from the lamps being fixed near the walls. The question might be asked, "Where should the lamps be fixed in order to fulfil the physical requirements?" Let Fig. 30 represent the plan of a room 16×14 feet. The fire-place is at F, and the occupants will sit chiefly within 6 feet on either side. Less light will be required at the ends of the room, EE, than near the centre, so that if two lights are suspended as shown by the dots 4 feet from the wall on either long side of the room, there will be about as much light in the centre as there is next the longest walls. In fact, there is a fairly even distribution of light. We are now discussing light not coloured or toned down by shades. If there must be shades which descend below the lamps, then such a room will require six lights. If the lamps are clear, and nice opaline or other reasonably transparent shades are used which allow the light to diffuse readily sideways as well as downwards, four lamps of even eight

FIG. 30.—Arrangement of Electric Lamps.

candle-power each are ample. Now the occupants rarely sit nearer than 2 feet to the wall, even in an arm-chair by the fire, whilst 4 feet at either end of the room is mostly unused unless the family is very large, hence the light within 2 feet of the wall is not of much consequence. The family sit, however, with their backs close to the table in a dining-room, or within a distance of 3 or 4 feet from the fire. If the illumination of the outer width near the walls is ignored, as it may be, and the lamps are closed towards the centre 2 feet on either side and 3 feet at each end, what happens? The lamps will then occupy just the position which they did in the old-fashioned four-light gasalier of fifty years ago. Our forefathers were not so stupid as some of us suppose them to have been. It was mentioned in the last chapter that the gas lights should be 2 feet apart, and it has just been noticed that by the last arrangement the electric lamps would be about that distance when four of eight candle-power were used. Four single lamps independently suspended from the ceiling at a distance of 2 feet would not look well, hence the central electrolier will be found to be the most serviceable as well as the most elegant. What was stated about the incandescent gas burner in the last chapter, that it is best to have the light behind the back when one reads, so as not to try the eyes, is a further inducement to depend upon a central electrolier for the principal lighting of a room. The wiring of the electric light enables the central electrolier to be raised or lowered with great readiness, and it is a very decided advantage to be able to do this. It has been seen how greatly distance reduces the power of a light, hence the privilege of being able to bring the lamps close to the table when one is at work there.

A word of caution is necessary with regard to the number of lamps and their candle-power which are required in living and other rooms. If the house is to be wired by those who supply the electricity, and there is to be an annual charge or additional percentage to pay upon each unit consumed, it stands to reason

that it will be to the benefit of the wiring company to put in as many lamps as possible of the highest candle-power, and the tenant has to pay the piper. Moral.—Wire the house yourself, and if it is your own do it under any circumstances. If the house should become empty—well, the wiring company will have the best of the bargain. If the house is not your own, and the landlord has given his consent to have the wiring done, avoid unnecessary lamps. To this end it may be useful to state from many years' personal use and experience of the electric light what lamps are required. A strong glare is to be avoided, and is generally regarded as detrimental to the eyesight. Still, it is possible to have nice quiet light of ample intensity, and by using the same lamp-holders to have a flare up or bright illumination if the tenant desires. If you have to order the wiring to be done, make sure that the electrical engineer employed does not join up too many wires in *one* circuit. It is better to have an extra circuit, so that when one substitutes sixteen candle-power lamps for those of eight candle-power, the quantity of electricity shall not be too much for the safe working of any circuit. The room is 10 feet square—one lamp of sixteen candle-power will light it nicely. But two lamps of eight candle-power consuming say the same amount of current will light it better, and, furthermore, the tenant can have "sunlight illumination" by changing the eight and placing sixteen candle-power lamps in their places. With regard to the two eight candle-power lamps being better than one sixteen candle-power lamp, the reason has been noticed already. Thus, if, as it was shown, the light at one foot from a lamp is eight candles and at 2 feet distance only two candles, it would be much more economical to use twice as many lamps of small illuminating power instead of half the number of double the value. In a room not larger than 14×12 feet two eight candle-power lamps renewed at Christmas, Lady Day and Michaelmas Day will give a reasonable light if good English lamps are used, but with three the light will be ample. Three good lamps of eight candle-power alight at

one time will illumine a room 18 × 15 feet reasonably well if the lamps are renewed as above, and are not the common rubbish of foreign make which flood the English market, but with four lamps the light will be perfect. Avoid the cheap and nasty lamps which may be purchased for 9d. each. A good English make which is not blackened after using a month is cheaper at 1s. 3d. If one make of lamp does not resist becoming black, try another, as it is most important to avoid this imperfection. Whilst on the question of the number of lamps it will be best to mention each room separately. The dining-room is 20 × 15 feet—select a nice electrolier which can be raised and lowered, unless the tenant prefers a fixed pendant of elaborate iron workmanship. If he does, let it be fixed so that the bottom of the lowest lamp is 6 feet 6 inches from the floor. Four lamps of eight candle-power will light the room rather much when they are new, and if he wishes to light the room economically he will see that there are two switches. On one there is only the lowest lamp—the electrolier having three arms and one central lamp below the other three—on the other switch there are three lamps. Fig. 31, which represents a simple four-light electrolier, shows how the lamps are arranged with the one hanging down from the centre. When the other three only are lit the appearance is all right, and when only the lower lamp is lit the purpose thereof is manifest. The wisdom of this arrangement will be seen in this, that when the room is not occupied and the housemaid is laying the table, the single light only is used. If a quiet family meal is being served, the one lamp is switched off, the other three (eight candle-power each)

FIG. 31.—Electrolier with Four Lamps.

giving a very nice light. For a bright illumination one sixteen candle-power lamp is placed instead of the eight candle-power lamp in the centre, and the four lamps used. If all sixteen candle-power lamps are substituted, the light will be unreasonably bright. For a drawing-room 20 × 15 feet a similar arrangement in which the electrolier has four lamps upon two switches is the best. In addition to the four lamps there should be a plug by means of which a movable lamp for use at the piano can be attached. If a sixteen candle-power lamp is used for the central light, this and the piano lamp will be enough when no one is reading in the quiet family circle. If the rooms are not more than 22 feet long a five-light electrolier arranged on at least two switches, the central lamp being on one switch, will light it from the centre. Or the four-lamp electrolier may be used in the centre and one eight candle-power lamp upon a bracket at either end of the length of the room. When the room exceeds 22 feet a lamp should either be hung from the ceiling 2 feet from the wall or be fixed upon brackets near the wall at either end of the length. The author experimented for years with the Swan lamp for electric lighting, to see if electricity could be used so that it will compare favourably in price with gas. The point desired was to obtain the maximum light with the smallest expenditure of current. As the result of these experiments it is recommended that nearly all the new lamps *do duty first* in the room most generally occupied by the family. It is a capital plan to change the eight candle-power lamps frequently during the long evenings, say on 1st October, 15th December, 1st February and 1st April, and if this is done three lamps in a room 18 × 15 feet will give a very pleasant and cheerful light.[1] A silk shade over the

[1] It is assumed, of course, that the voltage is neither below nor above that stated by the company supplying the electric current, and that their dynamos are sufficiently powerful to cope with the demand. If the current is said to be 200 and it is only 180 the lamps will not give their full illuminating value. On the other hand, if the current is irregular, and frequently above 200, the lamps will be soon destroyed.

piano lamp in the drawing-room and another over a reading lamp may be used if necessary, but no silk or other shade which greatly obscures or hides the light. The lamps in the drawing-room should be changed immediately one is blackened, but if renewed in other parts of the house those previously employed from one to two months in the room most used, and which are not blackened, are put in position. New lamps should be used for the kitchen and changed frequently. The lamp in the hall should be sixteen candle-power for a hall 6 feet wide, but a lamp of eight candle-power will do in a hall 3 feet 6 inches or 4 feet wide. The shade surrounding these lamps should not be very obscure. If the front lobby opens out into a spacious hall 14 × 12 feet or more, a beaten iron or brass bar having a lamp at either end and another hanging from the centre is serviceable. If the centre lamp is of sixteen candle-power it will be quite enough unless the hall is to be used to sit in, when the other two could be switched on. Indeed, the three lamps might be of eight candle-power, and one will give quite enough light to enable the occupants to enter or leave the house. If the kitchen is large, a sixteen candle-power lamp 6 feet from the floor and hanging from the centre of the ceiling will be enough. Two eight candle-power lamps will be more effective. If the kitchen is not more than 12 × 10 feet, one lamp about twelve candle-power or two lamps of five candle-power each will be sufficient. One eight candle-power lamp *renewed frequently* will give a good light in a kitchen not more than 10 feet square. One eight candle-power lamp will be quite enough in a small bedroom, or in the bedrooms generally, if placed immediately over the dressing-table and not more than 6 feet from the floor. In the best bedrooms it is very pleasant to have one lamp on a bracket above the centre of the head of the bed, and one lamp over the dressing-table, whilst under the latter and through the top a wire is carried so as to supply current either to attach a hair curler, Fig. 27, p. 161, for the ladies' convenience, or for an electric kettle, Fig. 28, p. 162, to make a cup of tea or heat water for shaving.

If the plug socket is fixed upon the top of the dressing-table, the plug of the kettle or of the curler may be interchanged. The lamp above the dressing-table may be of sixteen candle-power, and one lamp here is ample. The lamp at the head of the bed can also be turned on if desired. Lamps of eight candle-power each can be used and will be found quite serviceable. As the offices and small rooms use most current compared with the number of lamps alight, it is most essential that these should be duly considered if the tenant is going to keep his bill down. The author has the electric light in all offices and in the servants' rooms. In the w.c.'s five candle-power lamps are used, and these are made for a higher voltage than that of the current supplied. For instance, the voltage of the current is 200, the five candle-power lamps are of a high 210 voltage. In the housemaid's pantry the lamp is hung right over the work, and is five candle-power, 210 voltage. The scullery has a five candle-power lamp fixed right over the sink. Five candle-power lamps are used on the landing and half landing, in the dressing-rooms, and in the furnace-room of the hot-water apparatus. By using these high voltage five candle-power lamps, the consumption of the current is reduced considerably—over 100 units per annum. The advantage of using the five candle-power lamps of a higher voltage than the current consumed is this—the lamps will last for a long time, years perhaps, and less current will be used than if the lamp corresponds with the current. Of course, the light is not so great, but in the small places mentioned a light giving a couple of candles is quite enough. Where the author is now living, the charge for the current is 6d. per unit, less 10 per cent. allowed for the tenant's wiring. A discount of 7½ per cent. off the amount of the gas bill is allowed if the latter is paid within two months. The reader will see that there is no advantage given to the consumer who uses most current, neither is there any advantage under this arrangement to keep the number of lamps as low as possible—hence the reason why the switches and candle-power of the lamps have been so planned

as to consume the smallest current. It is to the author's advantage to have lights throughout the house, using the lowest candle-power lamps of higher voltage than the current so as to consume less. This is the most economical plan that the author could devise, and he cannot see a better plan now. As to the cost. There are twenty-eight lamps and three plugs in the house, and the following figures show the charges paid for the four quarters of a year.

For the quarter ending December, 1903 . .	£2	3	7
,, ,, March, 1904 . . .	2	15	3
,, ,, June, 1904 . . .	1	2	4
,, ,, September, 1904 . .	1	6	6
	£7	7	8

These figures include charge for meter also, but £1 should be added to cover the cost of lamps for the year.

In the living-rooms mentioned above, provision is made for more eight candle-power lamps than are generally used, so that those who require a stronger light can turn on the two switches and use the full complement of lamps. When these are lit the illumination is bright.

The charge for the current varies in different towns, and so do the arrangements and regulations applying thereto. When the writer lived in Hampstead experiments were tried there to see to what extent electric lighting was dearer than gas. The result of these trials, extending over five years, showed that if the electric current was used carefully, and the lamps changed frequently on the plan given above, the cost compared favourably with gas, whilst the extra comfort and cleanliness were beyond dispute. The method of charging for the current differed from that in force in Beckenham, and, apart from the possibility of the tenant increasing his bill in a moment by simply switching on all the lamps, is regarded as a very satisfactory arrangement. It was as follows :—

"The meter-reader will read the indicator once a month, from October to March, inclusive.

"The consumer will be charged 6d. per unit until he has consumed a certain minimum number of units in each half-year, *i.e.*, January to June, and July to December, respectively.

"The above-mentioned minimum is the number of units the consumer would have used if he had consumed his average maximum current for one hour each day during the half-year, such 'average maximum current' being the average of the three readings of the demand indicator taken during the half-year. The charge for current consumed during the half-year in excess of the minimum number of units as defined above will be 2½d. per unit."

Before concluding this chapter it will be well to refer to the shades used for electric lamps. If they are required simply to prevent light being diffused in all directions, and concentrated in one part of the room, any strong metallic or other reflecting surface will be found useful. For kitchens and other offices iron shades enamelled white underneath will answer well for directing the light downwards. For living-rooms, shades are used most frequently for surrounding the lamps in the electrolier with a view to toning down the light, or around each single lamp, either for the same purpose or for effect. The shades selected should be as transparent as possible, as the amount of light obscured by them will vary from 30 to 75 per cent. The silk for shades should be either of the fine Japanese or Chinese make, because more light passes through these than through the other kinds. Heavy, dark dyes should not be selected, but those which are like the material, almost transparent. When one considers the colour and opacity of the shades for single lamps, be they imitations of flowers or otherwise, it is found that they rob 50 per cent., if not more, of the light. Indeed, many of these shades reduce the light by fully 75 per cent. Where a lamp is covered with a shade with a view to its being used for reading or for the piano, and the light will only be required to be thrown downwards, the silk need not be so transparent. The frame upon which the silk shade rests may

carry a powerful reflector underneath with advantage, so that the light may be concentrated in the direction required.

The tenant is strongly urged to avoid using silk shades for lamps. They are dust and germ traps. If eight candle-power lamps are employed, the intensity of the light is not great, and no weariness of the eyes will be experienced when naked lamps are used, if they are fixed in the proper positions. The lamps and shades should be kept clean, and it will be found that much more light will be given by the former if the glass portion is carefully washed. To do this remove the lamps from the holders, but on no account must the brass portion of the lamp or any of the connections be made wet.

An electrical exhibition was held in London at the Olympia last autumn and the most up to date apparatus was shown. Of electrical fans, nothing novel was exhibited. Apparatus for heating was largely represented, and it is satisfactory to note that some of the producers are supplying electricity now for heating purposes as low as one penny per unit thus making electric heating much more practicable. For lighting small spaces such as rooms in dwellings the ordinary Swan vacuum lamp still holds its own and the reason others are not mentioned is because no lamp is so suitable, so quick in action and so reliable for the purpose. Tenants may discard those lamps which are said to give much more light and consume less current, and the information on lighting given in the preceding pages is still up to date.

CHAPTER XI.

HEATING DWELLINGS BY HOT WATER. BOILERS AND PIPES.

HEATING by hot water is the most pleasant and effective method of warming dwellings from a practical and economic point of view. It is not more healthy, nor is it so easily regulated as electric radiators, but the latter are too expensive for heating a house. Compared with the actual heat distributed, there is no other method of warming which is so cheap and reliable. Only those who have used hot water for heating a house throughout, year after year, can adequately realise the unspeakable comfort of having halls, passages and bedrooms warmed to the temperature which one desires. Those who live in villadom only on rare occasions keep fires going in two sitting-rooms when the drawing-room and dining-room are alight, so that if any operation has to be performed in a room other than that in which the fire is burning, the cold in winter may be both unendurable and dangerous. The tenant of a house with three or more sitting-rooms can, if these be heated by hot water, use whichever he likes at any time of the day or night. If he has a den or study, and wants to write or smoke, he can do this with comfort and without inconvenience to any one else, whilst his wife can use the drawing-room at any time also. If there are children, and they are allowed on wet days to wander and play in the landings upstairs as well as in their nursery, the temperature is uniform, and there is no fear of catching colds. In the early morning, when the children wake with the light, they do not have to go into a room which is frigid, and all the more cold

because the fire has just been lit. The heat has been on all night, and the walls are warm and the room is comfortable even in the early morning. If a child is ill at night, and the nurse or mother has to take it into the day nursery or into any other room, that room is always ready without the necessity of lighting a fire.

These are some of the benefits which are enjoyed by those who have their houses heated by hot water, and, as the operation is neither costly not difficult to superintend, one is not a little surprised at first to find that so few houses are warmed in this way. The question might reasonably be asked, Why is not hot-water heating more generally adopted? There may be several reasons, but the chief two, probably, are the following. 1. The furnaces usually fixed are too large, and not provided with simple dampers arranged so that a servant can keep it under perfect control without much attention. In addition to this fault, they are in too many instances deficient in coke capacity, so that in the morning during cold weather the fire is out when the servant gets up, and has to be relit. The inconvenience of having the rooms cold in consequence of the fire going out can be well imagined. 2. In houses already built it is difficult to adopt hot-water apparatus where there is no cellar, perhaps, and where, if there is a cellar, no flue has been provided. This second objection does not apply of course to new houses in process of erection, and one can only express surprise that architects do not advise their clients to use hot-water radiators for heating.

In this very variable climate, there are months in the spring and autumn when a fire can only be maintained with difficulty, and, if it is kept in, and the gas is lit at night, the oppressive atmosphere in the sitting-room is very trying. Where hot water is used for heating, the chimney-flue is free from soot, and, if the room is too hot in the evening, the windows can be opened a little with impunity, and with much better result in lowering the temperature. Indeed it is by keeping the radiators in living-

rooms rather warmer than necessary if the windows are closed it is possible to have a large admission of fresh air from outside, and the enervating feeling in the spring at the inception of plant foliage, and in the autumn during the fall of the leaf, is scarcely experienced at all in the house. Even those who object to other persons heating in this manner, because of the loss of the bright, dancing fire flame, admit its value for warming during the mild days when it is too cold without some fire, and because the flaming fire reminds them then forcibly of moist, clammy, perspiring experiences.

Most persons who adopt heating by hot water raise the objection at first that there is no visible fire, hence much cheerfulness is lacking in the room, and they state emphatically that they could never do without fires in their homes, but before long the great comfort of a house well warmed is so apparent that the desire to see the fire becomes much less pronounced. If the tenant wants a fire in a sitting-room, he can have it, of course, notwithstanding the hot-water apparatus is in use, for all he has to do is to cut off the radiator supply and the room can be heated by a fire only, or the radiator may be used to supplement the fire as required. When the writer fixed hot-water apparatus in his own home his wife stated that she could not do without a fire, because the room would not be cheerful, and she was informed that fires were intended to be used in the living-rooms as before. Experience soon made manifest the comfort of being able to sit in any part of the rooms, and, although the writer thought he would like a fire in the dining-room himself, no fire has been lit there since the apparatus was installed. The cleanliness of the arrangement must, of course, be patent to all, and if the housemaid has to look after the furnace, the work entailed is nothing like so much as to tend one fire in a living-room, provided always that the furnace is suitable.

The first question to be dealt with in reference to heating by hot water will be the furnace. For ordinary dwellings a

very simple arrangement is all that is necessary and best for the purpose. The mansion or castle is as much a dwelling as a cottage, but the heating of large residential premises can hardly be pointed out in detail in a treatise of this kind, because the arrangement of the rooms and the style of building must determine largely the nature of the furnace to be used. For instance, a mansion built on the Italian principle, having a courtyard in the centre, is much better adapted for using one large water-pipe boiler, and distributing the flow and return pipes from one central point. If it were possible to force such a boiler to a reasonable extent all the days when heating would be required, it would be wise to adopt one large boiler built so as to economise fuel to the greatest point practicable. In this variable climate, when the temperature may be 35° F. in the morning and 50° F. a few hours later, it is not at all wise to heat from one boiler always, and it will be found as a general axiom that two or three smaller and simpler boilers, easily stoked and worked on the slow combustion principle, are as reasonable in their first cost, and considerably cheaper in the long run. A large mansion was recently heated with three self-contained, upright, welded iron boilers of the same principle and not unlike Fig. 32. These boilers were, of course, distributed in the basement beneath the castle, which was built chiefly in one long block. The advantage of having three boilers instead of one will be obvious to those versed in hot-water engineering, as the leads can be so much shorter, and the great loss which occurs in distributing over long lengths vastly curtailed. By using three boilers like Fig. 32, the heating of a large mansion would be much the same as that adopted in three separate houses.

Furnaces of the type of Fig. 32 are usually made in several sizes, the heating capacity being varied by the height as well as the diameter of the boiler. For instance, if No. 1, having a boiler 13 inches diameter outside and 16 inches high, will heat 150 square feet of radiator surface, a boiler of the same dia-

meter, 2 feet high, will heat 200 square feet of surface. If No.

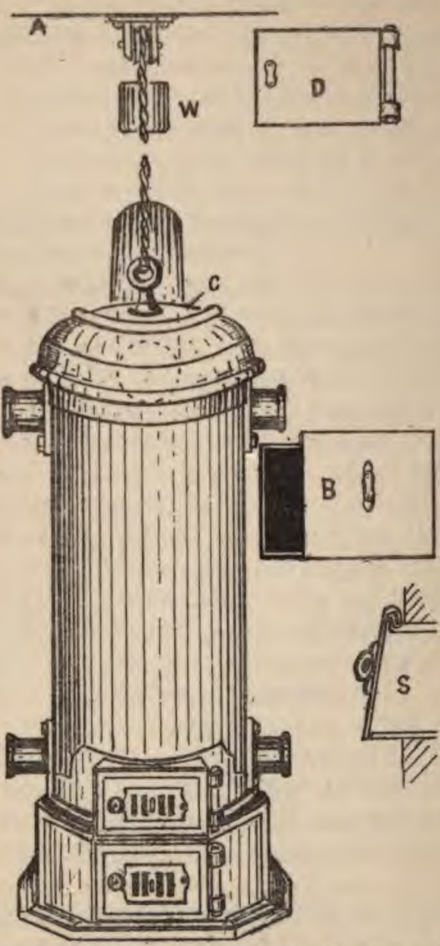


FIG. 32.—Boiler and Furnace with Flue Arrangement.

2, having a boiler 15 inches diameter, 2 feet high, will heat 250 square feet of surface, by increasing the depth a larger heating

power will be obtained. No. 3, having a boiler 18 inches diameter and 2 feet 6 inches high, will heat 380 square feet of surface. No. 4, having a boiler 21 inches diameter and 3 feet high, will heat 550 square feet of surface. These figures represent the square feet of radiator surface which can be heated by the boilers to 190° F. or more, and it may be assumed as a rough and practical calculation that one and a half times as many feet can be heated to 150° F.

For the purpose of fuller information, it may be stated that No. 1 boiler is suitable for heating a small villa with two sitting-rooms and four bedrooms. No. 2 will heat a villa with three moderately small sitting-rooms and five bedrooms, where the hall is not above 5 feet wide. No. 3 is suitable for a house with three fairly large reception-rooms, a good hall and seven bedrooms. No. 4 will do for a house with four reception-rooms, a good central hall and ten bedrooms. It generally happens that the size of each reception-room increases with the number provided, so that the total cubic capacity of the house which had three reception-rooms and a billiard-room would be nearly four times that of the villa with two sitting-rooms.

FIG. 33.—Boiler Top Showing Coke Cylinder.

The combined furnaces and boilers of the independent type upon the market are mostly lacking in fuel capacity, but are otherwise workable and satisfactory. There are, however, boilers made which are crowned at the top with a considerable length of cylinder intended simply as a coke supply, Fig. 33. The smoke pipe is taken off near the top of the boiler as in the drawing. The boiler for heating a house will generally be fixed in a cellar in the basement, and great precaution should be

taken to make sure that all deleterious gases will be prevented from getting into the room where the furnace is fixed. Where the smoke pipe is fixed as in Fig. 33, and the furnace is burning slowly, because there is a damper in the smoke pipe and it is nearly closed, the hot gases will ascend to the top of the coke and find their way around the cover into the room, especially if the weather is damp. This is no visionary or theoretical calculation, it does and will happen under such circumstances, and if the flue should be low and of a smoky character, the leakage will be aggravated. In fitting up hot-water apparatus this matter must not be overlooked, and it should be stipulated that in no case must the inside of the *coke cylinder be above the smoke pipe or orifice to the chimney*. Where no such extra cylinder for coke is provided, there is no necessity for the upper end of the boiler to be crowned with a long, tapering, sugar-loaf top and cover. The top shown in Fig. 32 provides much more coke capacity, and enables the boiler to be higher without increasing the actual height much over all.

The boiler of the furnace shown in Fig. 32 is 6 inches deeper than those like it in general use, and is very slightly conical inside to allow the coke to settle easily. To be conical is not of very great importance if the coke is broken properly, and this should be done in all cases, whether the boiler is conical or otherwise. The reasons given for the extra height of boiler suggested are two. 1. By having the boiler higher there will be more fuel capacity, the writer finding from experience that the boilers as now made would be much better if they had a couple of hours' extra fuel supply for winter use, so that they could be kept going well throughout the night. 2. Some boilers of this type have too little distance between the flow and return pipes. The consequence is that much of the water heated by a bright coke fire at the bottom rises straight up on the side where the outlet is, and into the flow, whilst the next moment the heated water on the other side presses forward in a slight rush to the same outlet.

The object of the hot-water engineer should be, as is more than once pointed out, to reduce the friction in the pipes supplying the ground floor of a house, especially when the height of the basement is restricted. It is best, therefore, to get as complete an admixture of the heated water in the boiler itself, and before it enters the flow, so that the whole supply may work smoothly. To this end it seems wise to adopt a boiler of the dome-top cylinder type. There is no doubt this boiler does mix the heated water thoroughly, but for heating a house where one of the servants has to attend to it, a boiler and furnace must be provided which can be filled with fuel easily, will hold a large supply, and one down which the attendant can look to see how matters are going. The independent boiler and furnace, Fig. 32, is recommended because it is simple in its working, easily filled, and the coke supply is large and can be inspected without difficulty. If the basement is lacking in height, the base of the boiler can be sunk somewhat, so that the boiler can still be 2 feet or more high, and what is lacking in admixture of the heated water can be compensated for by increasing the diameter of the pipes, especially the flow, by a quarter of an inch. The only reason why boilers of the dome-top and of the duplex cylinder types have not been recommended *is simply because it is more important to provide an easily workable boiler to one which costs two pence in attention to save one penny in fuel.*

It will be seen that Fig. 32 has a flow and return on both sides, and as these will generally be very serviceable in distributing the leads, they are strongly recommended, because there will be a more even admixture of the heated currents, and a more steady and equable circulation throughout. Independent boilers of the sizes styled No. 3 and No. 4 should always have a flow and return on both sides.

The cover C, through which the coke is supplied, has an under rim which rests in a groove, and as this is generally half full of coke dust there will be less chance for gases to escape

outwards, or for air to be sucked in. This cover is connected by a wire rope or chain passing over a pulley fixed to the ceiling to a weight W or counterbalance, which enables the cover to be raised and held up whilst the coke supply is being replenished. This is a useful arrangement. The furnace doors are shown as usually made, and are hinged. These are very liable to be strained by dust, and there ought to be no *ledge* under the bottom of the fire door. When a door is continually strained by dust and strongly heated it buckles slightly, hence any other and suitable door arrangement without hinges would be advantageous, provided it were permanent in character. Every care should be taken to prevent and remove dust before closing the door, because it is most important that it shall fit accurately. The writer has rarely come across a small furnace door which fitted nicely, and more care should be devoted to this matter, as well as to the hit-and-miss grid which should close perfectly. If these parts of the apparatus are carelessly finished, the servant in charge will be greatly handicapped, especially during the oft-recurring spells of close, muggy weather.

It will be noticed that the smoke pipe (which connects the furnace to the flue) and the part above the boiler is in one piece to prevent leakage of gases. The pipe is fixed at the *top* of the furnace, so that when it is filled with coke there is no chance for the fuel to plug up the outlet. Furthermore, the iron smoke pipe can be cleaned out easily by a wire brush such as is used for a cooking range. Thus there will be no need for any provision or opening in the pipe for the purpose. Joints cannot be prevented from leaking, because the heat will eventually crack any cement placed in them, and as the top above the boiler and the smoke pipe can be cast in one piece at an angle, as shown in Fig. 32, this should be done in all cases. The flue pipe should enter the chimney not less than 4 feet 6 inches from the ground in the case of a boiler 15 inches diameter and 2 feet 6 inches high. This will afford a working column of nearly 4 feet of hot air and fire, and such a column will keep the fire

going in mild weather when the chimney can get an unlimited supply through the door or sliding shutter B. To get this height of 4 feet 6 inches, the iron smoke pipe should be longer and more vertical in the case of the small boilers, whilst for No. 3 and No. 4 sizes the smoke pipe can be shorter and more horizontal. The diameter of the smoke pipe is important. It must not be too large, otherwise there will be a circulation of cold air down one side and into the coke space, causing combustion to take place at a quicker rate than necessary. For an independent boiler 13 inches diameter, a smoke pipe $4\frac{1}{2}$ inches diameter inside will do. A smoke pipe 5 inches in diameter will answer for a boiler 15 inches in diameter, and a $5\frac{1}{2}$-inch smoke pipe for a boiler 18 inches in diameter. A door D shown on Fig. 32 may be fixed close to the ceiling A leading into the flue. This door may be hinged, but should fit as accurately and air-tight as possible. It is intended for opening when, owing to bad clinkering, much fire has been removed and much sulphur has got into the room. If the furnace is fixed outside the house this door will not be required, nor will it be necessary when anthracite is used, but only if coke is consumed, but even then with care and a little thought it should not be often used. This door D must be shut directly the sulphur has been removed. The sliding shutter B, shown in section at S, is large, 10×6 inches, and forms a door through which air is admitted to reduce the suction of the chimney to the required point. Remember, a hinged door will not do unless it has a screw arrangement to make it stand securely at the point it is set, because a sudden gust of wind at the top of the chimney will often give rise to so much suction that a hinged door would be drawn to, and not unlikely cause the rooms to be overheated, and perhaps make the water boil violently. From Fig. 32, it will be noted that there is a free way from the bottom of the fire to the top of the iron tube entering the chimney-flue *without valve or damper intervening*. In those furnaces which have a damper or regulator fixed in the iron arm or flue to check the

draught, the gases arising from the fire will get under a slight pressure when the damper is used, and be driven out through the opening where the fuel is fed, because the cover of this opening will not be air-tight however well it is cast. According to the arrangement of the dampers in the illustration there must always be a partial vacuum inside the iron smoke pipe above the boiler, so that air will be drawn inwards through any chinks which may lie between the top cover C and the hollow rim in which it rests. The door B is fixed low in order that the chimney-flue may exert suction upon the air and gases in the iron smoke pipe.

In the writer's method the products of combustion are not checked by placing them under pressure and driving through a small outlet, but by reducing the suction power of the chimney in supplying it with cool air through B. Where the heat required is very small, the air getting into the furnace is cut down by closing both the doors and sometimes both of the hit-and-miss ventilators in front of the furnace. It is assumed in the foregoing description of the furnace and chimney-flue that the heater is fixed in a room in the basement of the house, and this should be done in all new houses wherever practicable. If the heater is fixed in a small outhouse or place specially built for it, the chief difficulty may be to prevent *too much* air getting to the boiler, but in the basement of a house it may very likely happen that no special provision has been made for additional, or indeed any, air supply. It is neither wise nor safe to rely upon opening a fanlight, window or surface light which is movable, and it will be well to fix a ventilator like Fig. 34 or Fig. 35 in the wall near the ceiling as far from the heater as possible. It will be best and cheapest to keep the room warm where the heater is, and, provided reasonable air is supplied, so that the chimney works well, it is wasting fuel to allow unnecessary air to come in. Hence if a ventilator 10 × 8 inches is fixed it will most probably be found that it can be shut when the air outside is 35° F. or less, but should be more or less open at all higher

temperatures. The writer has noticed that the room above the heater is greatly influenced by the temperature of that below, hence the volume of air admitted is carefully regulated.

In some furnaces, having a high column or reservoir for

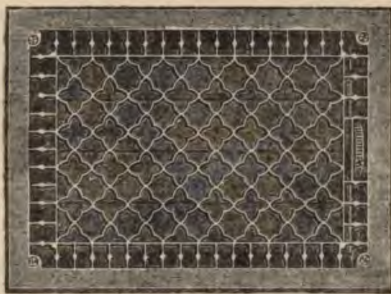


FIG. 34.—Ventilator for Boiler Room.

coke above the fire, the hot gases are not carried up through the coke, but pass into the flue at the back of the fire-grate. A damper is fixed at the bottom of this flue for regulating the heat. This is a bad arrangement, as the fresh air cools the flue

FIG. 35.—Self-indicating Ventilator.

at its lower end, and, when the boiler is working at a low temperature, there is much danger that carbonic oxide may escape up the coke chamber and issue into the room. It is quite possible for the air supply to travel backwards, and, unless

the cover of the coke chamber fits tightly, this chamber may become the smoke flue, and lead to unpleasant consequences.

With regard to the simplest way of working such a furnace as Fig. 32, the matter is not at all difficult. Experience has shown that, owing to the considerable proportion of ash in coke, and to the weight of the unburnt coke pressing upon the bottom of the fire-grate, the admission of air underneath the firebars through the lower door or the hit-and-miss grid thereof is not dependable. This is to be regretted somewhat, because the air getting into the fire through the grating in the upper door has to make its way from one side only, whereas that which would get to the fire under the bars ought, theoretically, to permeate evenly all over the bottom. Owing to the formation of more or less clinker and sometimes blocks of fused ash right across the bottom, it is found that the air obtained by opening the grating in the upper door disseminates just as well after the fire has burnt for a while as if it came in at the bottom of the firebars, when coke is used. In the writer's method of working with a *coke* fire, the lower door and grating are closed fairly air-tight, and this is recommended where the chimney-flue is high and there is a powerful draught, because at any time when the water has got cool through inattention in the winter the closing of the sliding door B will give rise to so much draught through the hit-and-miss grating in the furnace or upper door that the boiler will be rapidly heated. In *cold* weather the grating in the upper door is left nearly full open during the daytime, and generally at night unless the weather is very changeable and uncertain. If the coke space is filled up to the top at 10 or 10·30 P.M., for some hours the extra coke will offer resistance to the gases escaping, and although it may be necessary to keep the furnace working at night a little below the day temperature when the weather is severe and below freezing point for fear the coke supply will run out before the servant replenishes the furnace, it is rarely necessary to alter the grating in the upper door at all. The attendant will

find it a more simple method in winter to keep that grating in the same position night and day, and then open the damper door B slightly more at night. Indeed, the door B enables the apparatus in winter to be worked with simplicity and ease, whilst by its aid the furnace can be kept in during weather when the outside temperature is nearly as high as it is inside. During such mild weather, the grating in the upper door is shut, and the sliding door B is regulated so that the fire is kept alight whilst the temperature of the water in the boiler is not above 80° perhaps. The chimney-flue connected with the apparatus described is fully 35 feet high, and the draught is strong. In those cases where the chimney is lower, and the ventilating power less, the door B would have to be nearly closed perhaps. In the case mentioned, B is always nearly half open. If the flue is of reasonable height there will be no difficulty in regulating the air supply of the furnace, whilst the attention required will be small indeed. Should the draught or ventilating power of the chimney be strong, it will be best to always keep the door of the ash-pit and the door of the fire-grate closed, and the door B open sufficiently wide to prevent the water boiling in the apparatus when both the hit-and-miss ventilators in the above doors are full open.

English makers are now turning out dumping or shaking firebars to their independent boilers. These are useful for the larger sizes, but owing to the clinkering from coke, careful attendance is superior to any mechanical contrivance in the case of small boilers.

There is an idea abroad that it is cheapest to keep a small, quick fire burning freely so that all the carbon of the coke shall be perfectly burnt, and no carbonic oxide escape combustion. Such an idea is erroneous in every sense, and especially in those cases where slow combustion is resorted to. With a body of fresh coke above the incandescent fuel it is impossible to prevent carbonic oxide passing up the chimney, and, in those cases where the gases escape into the chimney without ascending

through the column of fuel which is situated over the fire, the pressure of the coke above makes sure that incomplete combustion will result, and that much carbonic oxide will be formed and escape up the chimney. Again, with regard to the question of cost of fuel consumed, it will be found that much more heat can be obtained from coke or coal by burning it with the smallest amount of air possible to keep up the heat required. This extra heat is due to the lesser volume of hot gas which escapes, and if that smaller volume enters the chimney at a low temperature, in consequence of the boiler taking up the most of the heat, the furnace works much more cheaply than if a larger volume of heated gases escaped, notwithstanding it is assumed there was less [1] carbonic oxide in the gases going up the chimney in the latter than in the former case. The writer did not think this was so pronounced until he had had considerable experience in tending a furnace himself. It was found repeatedly that when the temperature of the rooms got appreciably above 60° F., owing to a sudden rise of temperature outside, and the hit-and-miss grating in the furnace door was nearly closed with a view to check the heating of the boiler, the water increased in temperature rapidly instead of falling as one would expect,

[1] As a matter of fact, however, the proportion of carbonic oxide is generally greatest when a swift, bright coke fire is burning. The whole of the oxygen is rarely consumed whatever the condition of the fire, but if the latter is a deep body of coke at a white heat (2,000° F. or more) much carbonic oxide is formed, and although carbonic anhydride is not so stable at that temperature a considerable proportion of this gas is at once generated. In the case of slow combustion when the boiler is used in spring and autumn and the work upon it is small, the fire will frequently be only a few inches deep and the temperature not above 1,200° F. at the lowest part. Under these circumstances, whatever carbonic oxide is formed at first—and very little is formed—is mostly converted into carbonic anhydride as it *slowly* moves over dull red coals. On the other hand, the volume of carbonic oxide generated in a bright, quick fire is much larger and only partially converted into carbonic anhydride as it quickly passes through the top of the fire. The absence of hydrogen in coke prevents water being formed and much carbonic oxide being converted into the *anhydride* when a swift fire is burning.

and it became manifest that the best practical and only way to effectively reduce the temperature was to open the door B, leading into the chimney-flue, wider. The increased temperature which resulted when the air supply getting in through the grating in the upper door was checked was so appreciable that no doubt could exist that this was the cheapest method of procedure, and the experiment was tried so frequently as to leave no suspicion of the accuracy of the observations. Under the circumstances, therefore, if the hit-and-miss grating in the furnace door is *large*, it will be best to keep it only half open in winter unless the weather is very severe, and make up any want of air getting in by inducing extra suction from above, through the closing of the door B somewhat more or perhaps altogether. The writer has proved the great saving of coke which results from the closing of the grating in the upper door during mild weather, and has found that a bucketful will sometimes last for twenty-four hours by careful manipulation. If the foregoing regulations are reasonably observed, heating by hot water becomes both simple and inexpensive.

It will be best to mention here, probably, how advisable it is that the furnace and boiler shall *not be too large*. *Writers* on heating by hot water almost invariably advocate that the boiler and furnace shall be *large*, and that the error shall always be on the side of largeness rather than otherwise. Experience has shown that in dwelling-houses in England it is most unwise to allow spare boiler room, so as to make sure that there shall be more than enough heating power when the temperature outside is below freezing point. In America this must be done, but for economy and providing an apparatus which shall be workable in mild weather, the furnace must not be unnecessarily large. During the few days or weeks when the temperature is below freezing point in this country, there would be no difficulty to supplement the heating in the living-rooms at a push by fires if such a necessity arose, and this would be better than having an extra large furnace. Or the tenant may do as the writer does. The living-

rooms and bedrooms unoccupied have their heating cut down, so that the thermometer stands at about 40° F. When this is done the dining- and drawing-rooms or billiard-room can be heated fully, and the apparatus will give satisfaction. There is much fuel saved by under- rather than over-furnacing the hot-water apparatus, but *this is not the only advantage*. If the furnace is overlarge it is impossible to work it unless there are 10° difference between the temperature of the air outside and that inside, hence when the apparatus should be of chief value, *viz.*, in spring and autumn and often in the summer, it is not available. It was stated at the commencement of this chapter that the reason why hot-water heating was not more widely adopted was because the furnaces fixed were too large, and this is undoubtedly one of the chief reasons. A living-room at 52° F. is chilly and unpleasant to sit in, and unless the apparatus will work when the difference of temperature outside and inside is only 8° F. it is not suitable for a dwelling-house. The writer frequently keeps the furnace going for days together in the summer when the weather is damp and chilly, and the comfort is most enjoyable, but this could not be done with the plant ordinarily fixed, as the furnace must be put out directly the water gets a little warm, otherwise the air would be overheated or the coke fail to burn. In this country the sizes of the furnaces given above according to the number of rooms in a house should be noted, therefore, and followed closely.

In a No. 2 furnace the distance between the flow and return pipes should be 2 feet. It may be as well to deal with the question further at this point. It is advisable to take the flow and return pipes which supply the house other than the ground floor independently as close as possible to the boiler, and if a No. 3 boiler is used it is best to have a flow and return on both sides. If the upstairs radiators have their pipes leading out of those which feed the sitting-rooms, the flow should be at least $1\frac{1}{2}$ inches if not 2 inches in diameter, and there should be a valve in the hall, or other convenient place, by which the flow in the

pipes going upstairs can be regulated. If the living-rooms of a small house are heated exclusively by hot water, it is best *not to take a vertical pipe (for heating the rooms above) at the level of the ground floor from any supply to the living-rooms, and especially from that to those most generally in use*, but let the flow and return to the reception-rooms, whether the system used is the one pipe or the double pipe, be continuous and uninterrupted. If this is done, it will be possible to cause the circulation in the radiator of the room chiefly used by the family at night to be rapid, so that there shall not be many degrees of difference between the water at the top of the radiator and that at the bottom. However carefully planned a hot-water apparatus may be, it is not possible by natural means to get the water hotter at the bottom of a radiator than at the top, but this is what one would like to have so as to heat strongest where the coldest air lies. It will be seen, therefore, that it *is a great advantage to have a rapid circulation through the radiators on the ground floor*—in the first case because the heat is much more effective at the bottom of a radiator than at the top, and in the second place because where there is quick circulation it is a sure sign that the friction in the pipes is not the cause of *much loss of heat.* To get a quick circulation there must be either a large flow and return or a good vertical column or height between the level of the flow pipe on the ground floor and that of the return pipe as it joins the boiler. This latter provision is not always available in the case of the ground-floor supply, but it will be noticed that the difference in density between the water in the flow pipe and that in the return pipe leading from the *first* floor to the basement will be enough to cause rapid circulation and overcome the friction, provided the pipes are large enough, whilst the supply to the second or third floors will be too rapid proportionately unless the diameter of the pipes is reduced, or a valve is inserted to check the rapidity of the movement. All the pipes to and from radiators should be carefully covered with hair-felt one inch in thickness, or slag wool, but even then there will be an appreci-

able loss of heat. Under the circumstances it is not wise to use pipes of unreasonably large diameter, else the saving of heat due to the lesser friction of the water inside may be more than counterbalanced by the loss due to that radiated by the flow and return pipes themselves. Architects of new houses who contemplate adopting hot-water radiators on the ground floor should see that the room in the basement where the furnace is to be fixed is *lofty*, certainly not less than 8 feet, otherwise it will be very difficult to get a rapid circulation and use radiators which are about 2 feet in height. In an ordinary compact house with four reception-rooms, it may be concluded that the pipes leading to radiators on the ground floor should not exceed 2 inches diameter inside. The actual heating surface of the radiators which a 2-inch pipe will supply easily at a temperature of 150° in the pipes is about 250 feet, but it is not at all wise to run more than three large radiators, or so much as 250 feet of surface on one lead of double piping if it can be avoided, hence it may be assumed that anything above a 2-inch pipe would lose more in waste heat evolved than would be gained by the lesser friction entailed. A $1\frac{1}{2}$-inch pipe will supply two radiators each of 80 feet, or three of 50 feet of heating surface, especially if the lead is not unreasonably long, so that three rooms 18×15 feet can be heated on one lead of $1\frac{1}{2}$-inch pipe, and give good circulation, when the bottom of the boiler is situated 7 feet below the floor. If a small room on the ground floor is so situated as to require a separate lead, the pipe must not be less than $1\frac{1}{4}$ inches diameter, and if the difference in height between the flow and return is small it will be well to start the flow with a length of $1\frac{1}{2}$-inch pipe. It is a good plan to have a separate lead to the room which the tenant makes the general sitting-room in a villa containing only two reception-rooms, and which is to be heated *without* a fire, if the two-pipe system is adopted—that is to say, there shall be no radiators other than that or those for the room in question on that lead, *and* to use a $1\frac{1}{4}$-inch pipe, or $1\frac{1}{2}$ inch according to the height

above the return in the boiler, if that room is on the ground floor. Where the one-pipe system is adopted for the ground-floor radiators, the flow should commence its work if possible in the room chiefly used to sit in. When a new house is designed it will be quite possible to so fix the heater that the one-pipe system can be adopted for the sitting-rooms, and the flow arranged to heat the dining-room first, or the drawing-room if desired. In this case the heating surface must be greater in the rooms last warmed from the "one pipe," which will do its work best if the water is caused to circulate quickly.

If it is possible to fix the boiler and furnace under the hall of the house, and that hall is in the centre, no position could be better, as the leads would be short. In that case there should be a flue provided on one side in the wall of the hall, and here the height would be sufficient for strong ventilating power, and the flue, being in the internal wall, will be protected from outside variations of temperature. Never run less than $1\frac{1}{4}$-inch pipe up to the first floor unless one 6-foot length of $1\frac{1}{2}$-inch pipe has been used in the flow where it starts from the boiler, but thence one-inch pipe will supply a single room. Where it can be done without much difficulty, and especially if the occupant has a young family, it is a good plan to run the day and night nurseries on a separate lead, so that the circulation shall be good and it can be available when the other supply may be cut off. The flow pipe should rise into the *day* nursery, and the body of the radiator should rest (legs or no legs) at or below the level of the floor of the room. If it is practical to fix the radiator (with 3-inch legs) longitudinally with the joists it can be set in a trough 4 inches below the level of the floor, then the air at the floor level will be heated and the children's feet kept warm. The radiator should be of large surface for the size of the room, at least 20 nominal feet per 1,000 cubic feet capacity, then the instalment will be satisfactory.

Where the one-pipe system is used in the upper floors, the height of the legs of the radiator is not of so much importance,

but care should be taken to so commence the supply that the last radiator shall not have legs higher than 3 or 4 inches if possible.

Before proceeding further it may be best to point out all that is necessary in reference to single and double pipe work. It scarcely requires mentioning that the iron piping should be wrought, and the bends and joints malleable in all cases. Not much need be said about the difference between the single and double pipe methods, as practical men have mastered the matter in all large towns. The double-pipe system is the oldest and best known. It consists in all cases of a flow pipe from which one end of the radiator is supplied, and a return pipe connected to the other end of the radiator. The flow pipe leads from the top of the boiler and contains the hottest water, whilst the return pipe contains the cooler water, and enters the boiler at its lower end. If more than one radiator is supplied by one lead, each is connected at one end with the flow pipe and at the other end with the return. The chief difference between the two-pipe and the one-pipe system consists in this, that in the latter both ends of the radiators are joined to the same pipe, the hot water flowing through the pipe and radiators, until it eventually returns and completes the circuit as the pipe enters the bottom of the boiler. When a radiator is connected at both ends with one pipe, the movement of the hottest water through the radiator will be both slow and erratic unless the circulation through the main pipe is very rapid. Even then there will be a great irregularity in the supply, and one side of the radiator will not unlikely be much warmer than the other. To obviate this drawback to the use of the one-pipe system, and with a view to increase the circulation in the radiator, the joints of the connecting pipes are so arranged that the water as it moves through the pipe shall exert a slight pressure upon the flow into the radiator, and a slight suction upon the return into the main pipe. The illustration, Fig. 36, shows the arrangement of the flow to the radiator, whilst by reversing the

fitting to the return pipe from the radiator, so that the flow travels in the opposite direction, a slight suction is formed which favours the circulation of the water through the radiator. There are joints of this kind which have been patented, and they are both scientific and ingenious. The circulation through the radiator is rendered much more satisfactory by the adoption of these injector and ejector joints as they are termed. Care must be taken that the area of the pipe inside is not enlarged at the joints, however, otherwise the pressure or suction exerted by the flow of the water will not be obtained.

It is possible to run a single main nearly horizontal with a view to supply radiators on the ground floor, and after this is done to take it vertically either up to the top of the house at once, and thence supply the bedrooms in descending fashion, or the radiators on the first floor can be fed first, and so on, the return pipe perhaps doing no duty in its passage to the boiler. It is much better to heat the ground floor separately and to take another flow pipe close to the boiler and run it to the top of the house at once, but the pipes should not be carried across in the roof if it can be avoided, because of the waste of heat and material. As the main supplies radiator after radiator, there will not only be a much cooler current passing, but this vertical descent of the return pipe will cause considerable disturbance, which will be vastly more manifest in its results in warm than in cold weather. Whilst it is possible to have a house so planned that the one-pipe system can be worked easily, it must always be remembered that the system requires most careful arrangement to prevent failure. The author is somewhat strongly in favour of the one-pipe system when it will accommodate itself

FIG. 36.—Distributing Fitting.

to the special positions in which the radiators should be fixed. The main in one-pipe work should be as free from bends as possible, and so placed as to give the highest efficiency in circulation. To obtain these results it is not advisable to turn the pipe here and there, giving rise to bends and extra length of lead, in order that a radiator shall be placed in a certain corner of a room, hence it will be almost impossible to fix all the radiators in their correct and most desirable positions so as to work efficiently if the one-pipe system is carried out exclusively. The question must arise, therefore, shall the one-pipe system be adopted, and sacrifice the best arrangement of the radiators, or shall the two-pipe system be used in part or whole, and the circuits be planned just according to the aspect of the rooms upstairs and the purpose for which they are used? In warming a house in a street or a semi-detached villa having a hall on one side and the rooms compactly arranged, one would not hesitate to use the one-pipe system, starting the flow of the main to supply the dining-room or largest living-room, the return being used to heat the back room and the hall after doing service in the bedrooms. With a double house having a wide hall and rooms on either side, it is possible to use two leads and do the heating much in the same way as before, using the one-pipe system, but the writer is convinced that the arrangements of the radiators in rooms exposed to different aspects, and having one, two or three walls subjected to the cooling effects of the outer air, is a matter requiring much more attention than the simplicity of a system, if indeed the one-pipe method can be said to be more simple than the double, a matter upon which experts not unnaturally differ. On this account no illustration is given of the drop system, the complete circuit system or one-pipe method, although there are houses in which one of these could be used so as to have the radiators placed satisfactorily, but each house must be considered separately and distinctly, adopting one system or a combination of systems as will best suit the design and the situation of the structure. Some makers of radiators

supply useful particulars of the pipe systems, and their figures are more reliable than those mostly given in books on heating. In very cold weather, when the full benefit of hot-water heating should be at command, the radiators at the return end of the "one-pipe" main cannot be supplied fast enough to give their maximum heating power. It may be argued that the valve attached to each radiator enables it to be regulated so that it does not take more than its fair share of heating. This may be and is doubtless true, but it is found from practice that this apportionment of the supply is beyond the average servant, and whilst, as already stated, the writer's housemaid works the "heater" almost perfectly, no one in the house seems to be able to adjust the valves so as to control the supply in a different manner except himself. The drawing-room is usually kept at 55° or so, and is supposed to be regulated by the female portion of the household when the temperature is required to be higher, but the times the writer found it cut off altogether, or otherwise badly adjusted, have been so numerous as to make him have little faith in the scientific and nice adjustment of the radiators on a one-pipe system by the servants. During the periods of the year when the temperature outside is 50° or more, it is not easy to work the day nursery or other upstairs room or rooms requiring a reliable quantity of heat by the one-pipe system in a satisfactory manner. The actual temperature of the water in the main is comparatively low, so that the circulation must be necessarily very slow if the pipe is of reasonable size. Under these circumstances, even if the joints leading to and from the radiators are supplied with bends as shown in Fig. 36, the movement of the water through the pipe will not be sufficiently rapid to affect the circulation through the radiator, and the *one-pipe system is weak in this particular.* It may be argued again that all the other radiators could be cut off perhaps. In this country where there is frequently a rapid rise or fall of 20° of temperature, the heating arrangements must be made so that all which is necessary for the servant or attendant to do is

to heat the water more or less according to such variations of temperature. To ensure this the engineer, in planning the apparatus, will do well if he can make sure that the radiators in the living-rooms (among which the day nursery must be counted) have a constant supply of the hottest water, whilst the bedrooms and corridors or landings can be cut off, or their supply decreased by a single valve placed in a position easily got at by the tenant. If a riser can only conveniently ascend from a main leading to a living-room on the ground floor, special joints are on the market which favour the flow of the hot water to the lower radiators as in Fig. 37. The writer has already stated

FIG. 37.—Distributing Fitting.

FIG. 38.—Valve for Radiator.

that if more than one radiator is supplied on the upper floors from such a riser, a tap should be inserted at a point easily got at, by means of which the circulation can be regulated.

One valve, Fig. 38, fixed on the flow pipe of each radiator is all that is required for regulating, but for a dwelling-house it is advisable to have it nicely made and nickel-plated. The extra cost for a small house will only be a matter of shillings, and the better appearance will be worth the money. Floor-plates, Fig. 39, in the living-rooms especially, are recommended. These are made in two halves so as to cover the pipes coming up and going down through the flooring boards in the various

rooms, and the nickel-plated collars or floor-plates on the market give a nice finish to the work. The small taps,

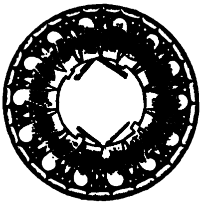


FIG. 39.—Floor-plates.

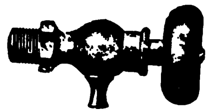


FIG. 40.—Air-cock for Radiator.

Fig. 40, fixed in the radiators to remove air should match the valves and be nickel-plated likewise.

CHAPTER XII.

HEATING DWELLINGS BY HOT WATER (*continued*).

RADIATORS.—Much observation and experiment have been expended upon the theoretical heating powers of radiators, and considerable information of scientific value has been obtained. There are, however, quite enough books dealing with these matters, which give all the formulæ for calculating the heating surface required, as well as other figures and equations. The unfortunate part of these formulæ and calculations is that they are absolutely beyond the brain power of the average hot-water engineer, whilst the difference between theory and practice makes it unwise to rely upon such calculations, even should the grasp of the engineer be sufficient to profit by the deductions mentioned. Experience has shown that some rooms are peculiarly warm and the temperature easily maintained in winter, although some of the walls are necessarily exposed to the outer atmosphere. Other rooms facing or, worse still, at an obtuse angle to the prevailing winds, especially if these blow from a cold quarter, are most unreasonably cold. If such rooms are situated at an elevation so as to be above other houses, and encounter the full force of the wind, the amount of heat required in winter is altogether beyond the ordinary limits recommended in text-books. Such is the case with a nursery in the writer's house, which is situated on the top of a hill. Under these circumstances, it is not possible to devise a hot-water system effectively unless one knows the situation, the prevailing

winds, the nature of the subsoil, and whether the surrounds are damp or low. A house in the neighbourhood of much water, near a lake or river, will not only require more heating surface in the radiators to maintain a certain temperature, but most persons will ask that the actual temperature of the rooms shall be kept always higher than is the case in dry or hilly districts. A damp atmosphere robs the heat from the hands and face at a much more rapid pace than does a dry atmosphere, hence a room in the former case would not be as pleasant under 63° F. as one in the latter case at 60° or 61° F. The writer, therefore, will be pardoned by the practical engineer if he dispenses with tables and equations, relegating to the appendix just those which may be of service to some readers.

There are many points relating to radiators having a practical basis, which it will be wise to consider, and these bear, perhaps, more upon the subject of dwellings than upon hot-water apparatus used for other buildings. The observations which follow have been all made by the writer with radiators fixed in living-rooms and are, therefore, specially relevant to the present subject. Other observers have noted that all radiators are not equally effective in heating, notwithstanding the measured surface and temperature of the radiators may be the same. It has been pointed out how the single radiator is the most effective heater for the surface exposed, but it has not been shown why this is the case, excepting so far as to indicate that where the surface is most exposed to the moving air more air particles will absorb heat and pass upward by reason of their lesser density. It is in harmony with this conclusion to deduce that where a section or loop is divided, so as to have two or more air columns between the water spaces, some portions of those air columns, especially at their upper ends, will interfere with the free upward passage of the heated air and so cause less circulation, with the result that there will be greater heat in the air which does escape. All these conclusions, whether from actual experiment or otherwise, are natural, but in every case it

has been assumed that the current of air is fed from below, and ascends vertically as it is heated.

Unfortunately, this assumption is not correct because the air in being heated by the radiator does not ascend from the bottom of the room and move upward in a vertical, uninterrupted column as is supposed. The writer has experimented with radiators up to four columns wide, with the result that in all instances there is much less movement of air from the floor upwards when the radiator has legs of 3 inches or more than one would expect. This is especially the case if the radiator is fixed near a wall, as is usually done, but in whatever position it occurs the layers of air at 6, 12 and 18 inches above the floor

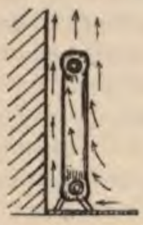


FIG. 41.—Supposed Air-currents by Radiator.

FIG. 42.—Actual Air-currents by Radiator.

always take part in the heating, and even if the radiator is 40 inches high, it will be found that the air 35 inches above the floor forces itself to some extent into the upward current of warm air. From the result of repeated experiments the writer was surprised at the small volume of air moving upward directly under the legs of the radiator, especially as the temperature of the air at the floor level was always appreciably higher than was the temperature of the air outside. The reason of this lack of vertical air movement immediately underneath the radiator is the continual pressure towards the wall of the air 6 inches from the floor and above, so that the heated air, instead of rising direct as in Fig. 41, moves as in Fig. 42, which shows that the air at 12 inches above the floor passes between the

loops of the radiator and is pressed forward against the wall into the ascending warm current. Under these circumstances, the pressure against the warm air from the front of the radiator prevents the free play necessary to the greatest effect from a given heating surface, whilst if the loops have two or more columns the interior air spaces will not be nearly so effective as the back and front surfaces of the radiator. This forward pressure of the air, too, will cause not only the imprisonment of that in the interior spaces, but what air does escape will be at a high temperature, resulting in a still further squeeze against the wall, owing to the much less density of the heated air at 2 feet, perhaps, above the floor. From these experiments two very important deductions may be drawn, whilst the wisdom of using single-column radiators will be further emphasised. The first of these deductions is that a radiator standing upon legs which lift the body several inches above the floor level is not adapted for heating the air close to the floor. The following refers to a two-column radiator in a living-room with which the writer experimented. The body of this radiator was about 29 inches high and the legs were 3 inches, so that the top of the radiator was nearly 32 inches from the floor. The temperature of the air outside was 34° F. Inside at the floor level near the bay-window it was 51°, and farthest from the window and from the radiator 52°. Three feet from the floor it was 56°; 6 feet 6 inches above the floor, 61°; and near the ceiling 65°. The room was lit by the electric light, but the figures given above were readings by daylight. When the electric lamps were lit the temperature at 6 feet 6 inches from the floor rose 2·5°, whilst near the ceiling (10 feet 6 inches above the floor) the temperature was 67°. These figures and many other observations show that there is a great difference between the temperature of the air at the floor level and that near the ceiling even where the electric light is used, and they show, too, that if the temperature of the air at the level of one's head when seated is 60° F., that of the air at the floor level is frequently 5° or more below,

according to the volume of air circulating. Furthermore, it was found that the difference per foot high increased the nearer one got to the floor level. There is generally a difference of 2° and often 3° between the air at the floor level and the air one foot above, and figures like the following are frequently found. Floor level, 51°; 6 inches above, 52°; 1 foot above, 54°; 2 feet above, 55·5°; 3 feet above, 56·5°; and when the outlet is the ordinary chimney-flue about 1½ feet from the floor such figures are often obtained. If the living-rooms are to be heated by hot water alone and no fire used, it stands to reason that when one's face and head are comfortably warm, the hands would be cooler, whilst the feet might be, and often are, uncomfortably cold. This is a most important consideration, and there is no doubt that fault has been found frequently with hot-water heating in living-rooms because the temperature of the air was so low at the floor level. The same objection can be found with the temperature of the air near the floor if the room is heated by a fire, especially if one is sitting where the radiations do not fall upon the feet, but it is generally possible to move towards the fender when there is a fire, unless there are too many present, and experience the benefit of the radiant heat. It is possible, too, to have a suspender which hooks upon the radiator, so that one can place the feet against the loops and warm the feet effectively, but this should only be resorted to by those who have indifferent circulation, and there is no necessity that the air at the floor level should be so cold. From experiments in churches, the writer has found that when hot-water pipes are fixed under the floor, and the air grating above is wide and the air spaces large, the difference between the temperature of the air at the floor level and at 3 feet above is often scarcely noticeable. If such is the case it may be concluded that the best method to heat a living-room is by hot-water pipes below the floor, and there is no doubt this is so, but it is so necessary to keep the pipes scrupulously clean and free from dust and flocks that, however perfect the heating,

the principle cannot be recommended. Radiators kept at a temperature of 150° and free from dust are perfectly odourless, and in the highest degree sanitary, but pipes which are below the floor, and cannot be got at so as to be dusted twice a week or more, are liable to smell, and it is scarcely possible to keep the hot air free from odour.

As it is absolutely advisable and necessary to heat the air at the floor level so as to be comfortable for the feet, it is possible to get over the difficulty by setting the radiator in a trough 4 to 6 inches below the level of the room. If the radiator is fixed lengthwise, so as to lie between the joists and the wall, it will not be at all difficult to keep the legs below the floor level. In this way the air from the floor will flow into the trough, become warmed and rise upward, although more or less pressed against the wall by the air above the floor level. If a new house is being built, it will be a simple matter to strengthen the joists or build a dwarf wall to support them, so that the radiator can always stand some inches below the floor. The legs of the radiator can be rather less than 3 inches, and the trough, under the circumstances, could be correspondingly shallow, but to be effective the *body of the heater must be at the floor level* and room for some air to get under it at that. Radiators which are suspended against panelled walls, or in other positions some distance above the floor, are not suited to heat with comfort, and should not be used in living-rooms.

The second deduction from the experiments above recorded is that the air must escape above the top of the radiator at the *lowest temperature possible* compatible with the surface and temperature of the radiator. To this end *the loops of the radiator must not be close together*, and one inch is a reasonable distance. There are plenty of radiators on the market not more than half or five-eighths of an inch between the loops. This is a great mistake, because the friction encountered by the air in making its way between the loops and columns is sufficient to prevent nearly one-half the heating value being obtained. Furthermore,

there is another important reason why the sections of a radiator should not be close together, or be placed in such a form as to allow the radiations to reinforce each other and be reabsorbed by the adjoining section. It has been briefly mentioned already that a radiating body, say at 120°, 150° or 200° F. has a peculiar aptitude for absorbing radiations given off by a body heated to a similar temperature, hence it will be seen that if some of the radiations from one loop or section at 120° F. can get across to the next loop without being all absorbed by the air, they are at once absorbed by the section against which they impinge. It is, therefore, a decided loss to have much of this reabsorption going on, and it is always well to keep this fact in mind when selecting a form of radiator for a building.

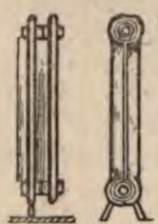
Again, the higher the radiator the greater will be the crush of the air against the front and towards the wall, so that it is most important to use *low radiators in order to conform with the physical laws.* It will be found, however, that what has just been mentioned is not only true from a physical point of view, but it is also *absolutely essential to the heating of a room comfortably and economically.*

Having decided where the radiator is to be fixed and arrangements made that the air shall be warmed at the floor level if possible, the next point is the form of radiator best suited. With regard to whether it is to be plain or ornamental, this may be left to the taste of the tenant, but a plain loop is the easier to clean, and on that account must be recommended. The height of the loop or section will depend in some measure upon the position where the radiator is to be fixed. If the most effective place for it is only 3 feet 6 inches wide the radiator cannot be 4 feet long, and it may be both wise and necessary to increase the height somewhat to get the surface required, but such liberties must only be taken after fully considering the situation. *The height of the radiator in all living-rooms should be limited to 26 inches, and 20 inches is more effective than anything higher.* A radiator with only one column can be higher

than another with three columns, and a single-column radiator 36 inches high will not heat the air so hot at 30 inches above the floor as will a 26-inch radiator with four columns. A single-column radiator need never be less than 26 inches high, anything above two columns deep is more effective at 20 inches than higher. The question will be asked perhaps, "In case there is only a certain width available, and either a 38-inch single-column radiator must be used, or a three-column radiator 26 inches high in order to get the required heating surface, which should be employed?" Always keep the heating of the air as near as possible to the floor in view, and, unless the engineer is faced with the problem that he must get all the heating possible out of a given surface—a problem to which one can scarcely attach much importance—it will be advisable to adopt the lower radiator. In such a case where the space was too narrow to employ a single-column radiator unless it was 38 inches high, the writer would not hesitate to use a four-column radiator, having a reasonable width between the loops, if he could get the required surface without exceeding 26 inches in height.

A single-column radiator is to be preferred wherever it is practicable to use it, but there is no reason why the sections should not be deep in order to increase the heating surface. The form of radiator Figs. 43 and 44 is not given as an ideal variety, but it is drawn because it presents many useful features. The water space is continuous throughout the width and the substance of the loop is only 1¼ inches. The width of the loop is 8 inches, and the heating surface 2½ feet when 26 inches high, with legs barely 3 inches from the floor to the bottom of the radiator, and the distance between each section is one inch. This radiator will give 50 cubic feet of surface if 50 inches long and 26 inches high. By having a narrow flange cast on one side of the radiator so that there shall be no pressure of air from the front to the back, as shown in the figures 43 and 44, the heating surface will be increased about one-third of a foot per loop. If this is done there will be a much more rapid circulation of air

underneath the radiator, resulting in the air at the floor level being more quickly and uniformly heated. There is no reason why this form of radiator could not be made wider for positions in which it would be suitable. Where there are two or more columns in a radiator, the inside air-spaces are covered over at the top, and their heating effects are not so good, but if a four-column radiator is selected see that it has at least one inch between the sections, and that they are so constructed as to be cleaned by a brush easily. There are radiators on the market like Fig. 45, but they are not so effective as the plain forms which have no divisions between the air-spaces to in-



FIGS. 43 and 44.

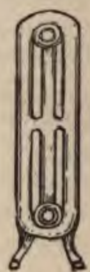


FIG. 45.—Radiator with Cross-pieces between Columns.

terfere with the free play of the heated air. Avoid all complicated forms, no matter how much surface they are calculated to yield. There are plain single-column radiators made for hospital work, which have extra width between the sections for easy cleaning, Fig. 46, and these will give 50 cubic feet of heating surface when 26 inches high with a width under 6 feet. Sanitary radiators of this kind are not only to be recommended on the score of cleanliness, but they fulfil the physical conditions required, inasmuch as they cause a large volume of air to be heated at a comparatively low temperature because of the little friction the air encounters, and the temperature of the air leaving the top of the radiator does not exceed 70° when the

water in the radiator is at 130° F. It may be contended also with much reason that if this hospital radiator is sanitary and easily cleaned, it is the very thing for the dwelling-house as well as for the hospital.

As heated air is so liable to stick and become imprisoned under covered surfaces, it is essential that no unnecessary metal be used in casting the waterway between the sections at the top and bottom. There is a radiator on the market of English make, and those who desire to patronise British manufactures

FIG. 46.—Hospital Radiator.

FIG. 47.—Radiator having Little Air Obstruction at the Top.

will see from Fig. 47 that it not only fulfils the requirement mentioned, but is also of a pleasing design. The purchaser should see that the sections are so bushed as to stand one inch apart.

The tapping of radiators should not be under 2 inches, and in all instances the bends and valves must have openings as large as possible, so that the circulation shall not be hindered or stopped when the temperature of the water is below 100° in the boiler. This is a most important consideration for the hot-water engineer who wishes to make his apparatus as workable

as possible when there is only about 5° of difference of temperature between the air inside and that outside.

Why is it so important to have a low radiator? In the first place the body of heat is concentrated near the floor level, and the air is caused to circulate more rapidly near the floor. With a low radiator it is necessary to use more sections, or loops as they are termed colloquially—hence the length of the radiator is greater, and there will be a more extended surface presented to the air at the floor level. This is of supreme importance, as the result will not only be a more gentle and certain circulation at the bottom of the room, but a more even temperature there also, so that comfort for the feet will be provided—a most

FIG. 48.—Circulation of Air in a Room.

FIG. 49.—Circulation of Air in a Room.

inestimable blessing in any living-room. Under these circumstances, the circulation of the air in the room will be like Fig. 48 instead of like Fig. 49, where the hot air is perhaps 90° or more as it leaves the top of the radiator generally used, and is pressed rapidly to the ceiling and much unnecessary heat is wasted there. The loss due to the air near a ceiling being at 70° or more is great when one long side and two ends of a room are exposed to the outside air, but in any case, the loss due to what the writer pointed out, *viz.*, the natural pressure as the result of the difference in temperature of the air above the entrance to the chimney and the top of the room compared with that below the entrance to the chimney, in addition to

the adverse cooling effects of the outer walls, must always be considerable. Nor is this all, because the circulation is rendered much more difficult the warmer the air is, and hot air forms a stratum near the ceiling which is very slowly changed by diffusion. From every point of view, therefore, except just the matter of the first cost, the radiator should be low, and the distance between the sections one inch, so as to enable the largest volume of air possible to pass up the heating surface exposed. In a dining-room the top of the table generally influences the flow of the air towards the radiator, especially if it is fixed about the middle. The temperature at the top of the table should be appreciably higher than it is near the wall on the other side of the room at the same height, because the warmed air from the radiator passes over the top of the table to supply the place of the cooler air which has found its way under the table to the heater.

The advantages of having a low, long length of radiator in preference to its being short and high have not been exhausted yet. The local currents supposed to be formed by some authorities, and possibly may be formed, so that the hot air leaving the radiator ascends to the ceiling, crosses it and at once enters a chimney-breast ventilator without taking practically any part in the ventilation of the room, cannot be formed when low, long radiators are used. A glance at Fig. 49 will show that in the case of the high radiator kept at 190° or more in cold weather, the velocity of the ascending currents of warm air is too great to allow such circulation as is shown in Fig. 48. It will be seen, too, that there is a line drawn physically above which the heated air *must ascend to the ceiling* rather than circulate within 2 or 3 feet from the floor as it ought to do. This line may be indicated by a temperature of 80° in the air as it leaves the radiator 3 feet above the floor. Again, if the length of the radiator is 6 feet instead of 3 feet, the surface over which the heated air is spread is increased twofold, with the result that the admixture of the cool with the heated air will be

perhaps three or four-fold. Not only will the air near the floor be heated more equably, but the velocity of the currents in the room will be reduced so considerably as not to be manifest to the most delicate nasal organ. Persons suffering from hay fever or susceptible to sneezing which is induced by currents of air must either be half-asphyxiated in consequence of every crevice being closed in the winter, or suffer continually, but if the rooms are heated by a long length of radiator kept at a low temperature, perfect comfort and immunity from these troublesome affections of the nasal organs can be enjoyed.

Why keep the water in the radiator at a comparatively low temperature? In the first place it is not possible to have a heating surface above 150° F. without causing *appreciable* chemical action in an atmosphere where readily decomposable organic compounds are present even in trifling quantity. Hence the more the temperature rises above 150°, the greater the odour of air burnt by hot iron in the room, whilst the activity of the bacteria in the air is much increased. The currents of air in a room must vary greatly according to the movements of the occupants—especially ladies, on account of their dresses—and still more if a door is opened to the hall, which may communicate with the outer atmosphere either through another door or through a window upstairs. It will be seen, therefore, that it is impossible to avoid some breath being drawn down to the radiator and passing over its heated surface, hence the wisdom of keeping the radiator at as low a temperature as possible. Again, as already foreshadowed, it is likely that the air leaving a radiator 26 inches high kept at a temperature of 200° F. will be warmer than from the top of a radiator 38 inches maintained at 120° F. There is no line of temperature that can be drawn at which it may be said that the heating of a radiator is perfect at that point and imperfect at any other. Nor can the same be said with regard to heating by the radiations from a fire. The idea expressed in so many books on heating that *the term* radiator is a misnomer is not true. Radiators *do*

radiate as truly as a fire does, only the radiations have longer waves, and give rise to less heat when intercepted. Returning to the question whether there is any temperature at which an ordinary radiator is perfect for heating air, the answer is, that in all cases of heating the lower the temperature of the heater the lower will be the temperature of the air in the upper part of the room, providing the illuminant is the same, and the less decomposition of organic matter will result. What is wanted in heating a room is to keep it *throughout* as near as possible to the temperature at which the human body feels comfortable. If this is 62°, then the nearer the air approaches this, both at the floor level and *close to the ceiling*, the more perfect will be the heating. With this end in view, it will be seen that the best and only way to secure such a result is to use *as low and long a length of radiator as possible*, and keep the temperature of the water in the radiator at or below 150° F. When this is done, the comfort and health-affording virtues will be at their maximum.

It may be contended, even if the foregoing advantages are admitted, that such an arrangement would require a very much larger heating surface and increase the first cost of the apparatus. It would, but it might be well to inquire to what extent. If it is concluded that 40 square feet of heating surface is enough for a room containing 3,000 cubic feet of air, provided the radiators are about 200° F., it may be assumed that 60 feet of heating surface will be necessary so as not to heat the water above 150° F. when the air outside was at 32° F. All this may be true, and it is further admitted where a dining or other living-room is used as a smoking-room, which wants free circulation of air throughout the night after the occupants have retired, 65 square feet or even 70 feet would be an advantage. For a drawing-room rarely used, which can have its ventilators and registers closed, less heating surface will be necessary, because the walls can be kept warm by allowing little air to circulate when the room is not occupied. The tenant and the

builder who instals a hot-water apparatus when the house is in building must not forget to make sure that the grates can be closed air-tight, and that the chimney-breast ventilators are capable of being closed perfectly also, then the rooms can be kept warm through the night with the expenditure of as little heat as possible during severe weather. Let it be assumed, however, that one-half as much again of heating surface is required on an average in the living-rooms of a villa, which are three in number, and that 160 cubic feet of surface are necessary—what is the extra expense? A matter of £5 simply. Let it not be concluded from the above that this arrangement of long low radiators is recommended only for the living-rooms—it is an excellent method which gives the best results to have a large surface at a low temperature in the bedrooms—the corridors will also be more equably warmed and kept at a higher temperature for the same expenditure of fuel in the boiler by using this method, and being generous in the heating surface throughout the house. If it is calculated that the extra cost of increasing the heating surface of the radiators on this generous principle will be a matter of £15 for a house with ten rooms, surely such a sum is trifling compared with the benefits obtained. Furthermore, the tenant will have interest on the extra outlay returned to him when he pays his coke bill, for at least 30s. per annum will be saved. The amount of heat taken from the coke burned on the slow combustion principle, when the water does not exceed 150°, is vastly greater than the proportion absorbed by water at 200°.

The practical engineer, who is puzzled by equations and abstruse calculations, will doubtless rejoice in the apparent simplicity of the deductions. Moral.—Be most generous in the heating surface supplied, and, mind, do not make an error on the wrong side. Nothing could be more simple! It is not as simple as it looks. The tenant does not regard the presence of a long length of radiator as an ornamental piece of furniture, and there are considerations which make it as unwise to

err at all, in providing *overmuch* heating surface as in allowing too little, and the question of space is also important. The radiator must not be fixed too close to the wall. Such advice can be repeated with emphasis. If a clear 3 inches is allowed all the better, but the radiator must not be closer to the skirting at the bottom than 2 inches. Of course much will depend upon the form of the sections, and whether there is a good distance between them, but it is advisable to have at least 2 inches clear between the farthest projections of the radiator and the wall wherever possible. Another serious objection to the presence of excessive heating surface in a room is the difficulty of keeping the temperature low enough in living-rooms when the temperature outside is 50° or more. There is no question that this difficulty must be surmounted if the heating apparatus is to be effective. In the spring and autumn the atmosphere is often extremely raw when the outside temperature is fully 50°. The chilly feeling experienced is more due to the dampness of the atmosphere than to the actual temperature, but it is as real as it is uncomfortable. There is no time when a heater is more serviceable, and in order that the apparatus shall be workable the radiators must not have more surface than necessary. If the position of the room and the arrangement of the pipes are favourable to two radiators being fixed the heating will be more even, and one radiator can be cut off altogether in mild weather. Under these circumstances, the hot-water engineer cannot err much if he allows a large heating surface. He should make himself thoroughly acquainted, however, with all the difficulties of circulation when water is below 100° F. in temperature, and fix the pipes, joints and bends in such a manner as to ensure success in this particular, for it is here that partial or complete failure so often occurs.

The practical engineer may perhaps ask: "Cannot some reasonable figures be given as a guide to the heating surface?" They can, and the following table will give a fair idea of the heating surface which it is wise to adopt. It should be under-

stood, however, that all the local circumstances must be duly considered and allowances made for the heat of the pipes and hot-water tank to a bath on the one hand, or the peculiarly isolated, exposed or elevated position of a house on the other hand. If the boiler is in the basement under a living-room that room will be the most comfortable on account of the floor being heated underneath.

Table Showing the Number of Cubic Feet of Air Heated by One Square Foot of Surface to 62° F. when the External Air is about 32° F. and the Radiator does not Exceed 150° F.

Main Hall, Ground Floor	60 cubic feet.
Upstairs Corridors and Landings	70 ,,
Bedrooms facing east or north with 1 wall exposed.	60 ,,
,, ,, ,, 2 walls exposed	55 ,,
,, ,, ,, 3 ,,	50 ,,
,, south or west ,, 1 wall exposed.	65 ,,
,, ,, ,, 2 walls exposed	60 ,,
,, ,, ,, 3 ,,	55 ,,
Day and Night Nurseries	50 ,,
,, ,, if badly exposed to east or north on two or more sides . . .	45 ,,
Dining-room with 1 wall exposed, if used as family living-room and for smoking . .	47 ,,
Dining-room with 2 walls exposed . . .	45 ,,
,, ,, 3 ,, badly . .	43 ,,
Morning-room, if much used as living-room and for smoking	same as dining-room.
Drawing-room with 1 wall exposed . . .	55 cubic feet.
,, ,, 2 walls exposed . . .	53 ,,
,, ,, 3 ,, . . .	48 ,,
Billiard-room or Library	55 ,,
,, ,, badly exposed . .	50 ,,
Smoking-room	50 ,,
,, badly exposed	45 ,,

With the above provision the bedrooms will reach 55° *in severe weather*, and if the inlets and outlets are closed, they can be nicely warmed before the occupants retire, then as much air as

is liked can be made to circulate. The night nursery does not apparently need so much surface, but it must be remembered that the radiator can be regulated by the valve, and it is most useful to be able at any time to increase the temperature of the room in case of illness. *It is a most wise provision, even though a nursery is not used, to have a bedroom which can be consistently and strongly heated when required.*

No better position for a fresh-air inlet can be found than immediately over the radiator, and the supply should be so subdivided as to fall into the heated atmosphere rising above the radiator from one end to the other. In this way, if the inlet air falls from a shelf for holding pottery as described on page 68, it will mix with the warm current coming up and cool it, so that near the ceiling the air will not be at a high temperature and the effect in the room will be beneficial. If, however, there are two or three good-sized windows to a room, and some air has been allowed to rise from below the floor when the pipes were laid, it will generally be found that there is a fair supply coming in provided the chimney-flue is not blocked with soot and the friction upon the outgoing air is reduced. If the air supply is deficient, the inlet arrangement suggested is excellent.

Another most important consideration is that of the position which a radiator should occupy in a room. The general idea of most engineers is that it should be fixed in the coldest part immediately beneath the largest window surface, and this is the plan most frequently adopted in public buildings also. We are not dealing with places of worship, halls or other large buildings where persons sit near windows and experience the cold air falling directly upon them, but with dwelling-rooms in which persons *do not sit beneath windows under ordinary circumstances*. It will be as well to look closely into the physical conditions resulting from a radiator being placed immediately in front of a large window to see what happens. The hot air rises to the ceiling near the window, and there it is sub-

jected to the pressure which results owing to the difference in temperature between the air at the point where it gets into the flue by the grate and that which exists near the ceiling. Under these circumstances, the tendency is that much of the heated air shall escape through the crevices around the top of the window, and whenever the wind suction is exerted upon the window *outside* this leakage of warmed air will be aggravated, with the probability at times that there will be an intermittent down-draught in the chimney-flue making matters still worse. The second objection to placing the radiator under a window is the fact that *great and unnecessary circulation of hot air occurs right against the cold glass.* It is well known that the heating effect of a radiator depends greatly upon the velocity with which the air is made to impinge against its surface, hence a small radiator would heat much more air than a larger one if a fan was used to cause a sharp current to move against the heating surface. In the same way, naturally, the cooling effect of a refrigerator will depend upon the velocity of the air coming in contact with it. The glass of the window is such a refrigerator, and the radiator beneath causes a powerful current to move over it with the result that much heat is unnecessarily lost. To prevent this loss of heat at the windows the radiator should be so placed that the circulation over the glass is reduced as much as possible. On the other hand, care must be taken to provide that the cold air as it moves towards the radiator does not have to pass over the feet of persons sitting in the part of the room which is usually occupied. The plan of a room as shown in Fig. 50 is lettered in such positions as a radiator can be fixed. The radiator should not be fixed at A or B, because the cold air from WWW would pass over where the occupants chiefly sit at S, and a further objection is that if a chimney-breast ventilator is used and fixed above F there will be a tendency for the heated air to travel direct into it. If no chimney-breast ventilator is in position, and the outlet is through the usual fire-grate, the pressure of the cold air will

FIG. 50.—Position of Radiator in Living-room.

FIG. 51.—Position of Radiator in Living-room.

FIG. 52.—Position of Radiator in Living-room.

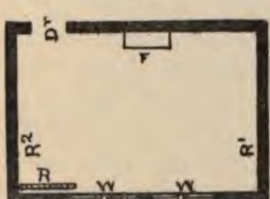


FIG. 53.—Position of Radiator in Living-room.

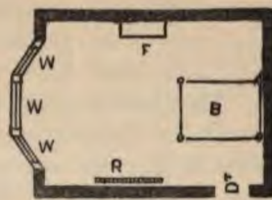


FIG. 54.—Position of Radiator in Bedroom.

FIG. 55.—Position of Radiator in Bedroom.

FIG. 56.—Position of Radiator in Bedroom.

FIG. 57.—Position of Radiator in Bedroom.

force the heated current right against the ceiling and towards the upper part of the chimney-breast, so that the air above the mantel will be much hotter than that at the other end of the room. The door is at D^r, leading into the hall, and if the latter is heated the best position for the radiator is at R. If the room is large and the window surface does not admit of much air coming in, and inlet air should be provided, the position at R is still preferable when the radiator will be near an outer wall, because the inlet air can be allowed to stream down as mentioned on page 68. If there is a window at W^1 in addition to those at the end of the room as in Fig. 51, the radiator is at R because the cold air will be led away from where the occupants of the room sit. Should the room be large, and the window space considerable, the best plan in the case of Fig. 51 would be to have a second radiator at R^1. With regard to Fig. 52, the arrangements of the radiator and the windows is such as to ensure the absence of draughts if the hall is heated, and when a chimney-breast ventilator is employed the heating can be made very satisfactory in a room having windows so placed. If the room is 30 × 20 feet two radiators fixed at R^1 and R^2 will give good results, and allow single-column sections not more than 26 inches high to be used. When the width between the windows is small, and the lead of the pipes will allow, two radiators are preferable. A room like this, 40 × 25 feet, would be very efficiently heated by three radiators fixed in the positions shown, R being the largest radiator, and R^1 and R^2 being placed a little nearer the middle of the end of the room. Fig. 53 is a room not unlike the preceding one, only the door is on the other side and the windows are a little differently arranged. If the hall is cool, it is very important to make sure that the air at the floor level flowing towards the heater does not travel over the feet of the occupants. If the hall is to be well heated, and the room is not above 18 feet long, one radiator at R will be satisfactory, but two radiators, one at R^1 and the other at R^2, will give the most

even heating, and if the room is more than 18 feet long two had better be used.

If the windows happen to be at the other end, or at the other side of a room like that given in one of the illustrations, place a small piece of tracing paper over the drawing, trace roughly and look at the under side of the paper, then the position of the radiator will be rightly shown.

As the position of the bed or beds in a room is an important consideration, some examples of how radiators should be fixed in bedrooms are given. W stands for window, F for hearth, R for radiator, and B in all cases is for bed. Fig. 54 has windows at one end, and on no account should the radiator be fixed under these windows, because when they are opened fairly wide it will probably happen that the air from without will fall upon the heater, and escape into the open without taking any part in the ventilation of the room. Where possible, the radiator should be near the centre of the room, and the position shown in the figure is very good. In Fig. 55 the best place for the radiator is between the windows, but where the width is small the radiator may be carried somewhat across the woodwork on either side. In this case, if a chimney-breast ventilator is in position, open the windows a little at the *bottom* when required. In Fig. 56 the radiator should not be fixed very close to the windows if it can be avoided. The radiator in Fig. 57 is best placed about half-way from either end of the room.

The writer does not think it necessary to multiply the illustrations showing positions of radiators. The following points should always be kept in mind. 1. The radiator is to be fixed, wherever possible, at the other side or at the other end of the room in which the outlet occurs. 2. In living-rooms heated by hot water alone it is imperative that the cold inlet air does not travel over the feet of the occupants as it gets to the radiators to be warmed, and in fixing the radiators it should always be assumed that no fire is to be lit in the room. 3. Avoid fixing the radiators under windows, and where only one

radiator is used place it near the wall opposite to the fire and equidistant from either end of the length of the room where possible. If the fire-place is at the end of the room, and the latter is long, the radiator is best fixed at the side about one-third from the farther end.

The arrangement of the radiators as shown will frequently interfere with the one-pipe system being used exclusively, but it is better to study the comfort of the occupants and adopt a two-pipe system where necessary. In no part of the house is it more essential to avoid perceptible air currents than in the bedrooms, hence it is not wise to fix a heater directly opposite the side of a bed; but, whilst this point is duly considered, the radiator should be fixed as near as is reasonable to the foot of the bed, in order to make sure that the foul air shall be efficiently removed from that part of the room.

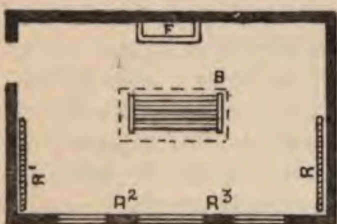


FIG. 58.—Plan of Billiard-room Showing Radiators.

For a billiard-room, when there are no other rooms above, and which will most probably have three walls exposed, a battery of pipes, B, Fig. 58, can be placed immediately under the table, shown by dotted lines, and supplied with a reasonable amount of inlet air, otherwise two radiators should be fixed or even three small ones if the room is very large. Low radiators will not interfere with the players as long as they are situated near the walls, and if the room is *wide enough* two such radiators, one on either side near the centre of the table, or one at either end so arranged as to prevent much movement in the air directly over the table, will answer well. If, however, the room is lit at the R end of its length, a battery of pipes can be fixed under the table and a double row of pipes placed under the floor across the windows. A radiator at R and another at

R^1 will be serviceable if the room has an outlet in the centre, and is lit from the side or from the top. In this case the battery under the table may be dispensed with. The hot air rises under the table and sticks there, getting into the room with difficulty, so that unless the battery is fed with fresh air from without, the heating effects are intermittent and uncertain. On the other hand, if the room is narrow for its length, the radiators should not be fixed near the middle, else the warm current will be drawn from either side over the centre of the table, and give rise to hot waves alike unpleasant and undesirable. This state of things will be aggravated as soon as the illuminants over the table are lit, especially if gas is used. If a battery of pipes is beneath the table the same effects are experienced as soon as the gas is lit, only they are alternated with cold douches of air if the wind pressure is exerted upon the inlet air grating. It is generally best, therefore, to warm the room from the ends, and fresh air can be admitted and warmed by letting it fall some three feet or more above the heaters with some such arrangement for subdividing as mentioned on page 68. Where the outlet is through the chimney-flue the radiators at the ends can be arranged as shown, but if the room is nearly as broad as it is long they could be fixed at R^2 and R^3.

With regard to indirect radiators, not much will be said, as they are not recommended for dwelling-houses. The term "indirect" radiator is generally understood to mean an arrangement at the bottom, or in some other part, for the admission of cold, fresh air from without, which is warmed by the radiator before getting into the room. If fresh inlet air is wanted it is best obtained by the shelf or some such arrangements already referred to. If this is done the hot current of air leaving the top of the radiator is tempered and cooled somewhat by the subdivided inlet air, and this method not only provides fresh air, but also prevents unnecessary heat getting to the ceiling of the room. Nor is this all, because the lower part of the radiator, through which inlet air is usually

admitted and warmed, is greatly cooled in the operation, with the result that the air in the lower part of the room is not properly heated and is consequently cool for the feet. Furthermore, as the inlet air comes through the lower part of the radiator it is impossible, without close supervision, to prevent much cold air escaping into the lower part of the room and diffusing itself more or less all over the floor, making it unpleasantly cold. There are "indirect" radiators on the market which admit the fresh air at the top through tubes in the inside of each section. During very cold weather these inlets act all right, but, owing to the friction which the air encounters in travelling up a narrow tube, the value of such indirect radiators is somewhat lessened during weather when most inlet air is required. If the radiators are arranged as pointed out in this chapter, the tenant will find it as easy to manipulate a window as the valve of the air inlet, whilst in severe weather the leakage through this valve will probably be enough to prevent the radiator being able to keep the temperature of the air in the room sufficiently high owing to the great volume which finds its way around the window sashes, etc. Indirect radiators are expensive things to buy and to fix, but if they are used because the house was constructed with that end in view care should be taken to ensure that the air inlet can be properly got at to be cleansed, and that it can be cut off as completely as possible when desired.

Before the radiators are fixed, it is usual to give them a primary coat of paint, and then finish off with two or more coats of the colour which may be thought most fit to match the surroundings. If the radiators are coated with a thin, dead black before fixing, having so little oil in it that there is no shiny appearance after drying, they can be covered with a coat of Berlin black subsequently, or, better still, with good black-lead enameline, and after some experience it will be found that the appearance of the radiator is all that is desired. There is no chance given to the maid to neglect the dusting, as dust is

at once visible on a black ground. If the radiators are painted to match the paper they may be of a colour upon which dust is not visible, and, furthermore, so much oil and varnish may have been used as to seriously interfere with the rapid emanation of the lower tones of radiant heat energy. If, however, the radiators are painted, and much oil and all varnish eschewed, the colour of the radiator does not interfere much with the heating powers. White metal paint, bronze paint or any bright, metallic coating is inadvisable, because it interferes with the quantity and frequency of the radiations. On this account Dutch foil and imitations of gold are to be avoided.

Among the adornments sometimes adopted for radiators are alabaster or marble copings fixed upon the top. The writer could never see where the decoration came in, but it was obvious that what was done was quite wrong from a physical point of view. The tendency of hot air to stick against horizontal surfaces, through the pressure of the cooler air underneath, has been mentioned more than once, and the covering over of a radiator so as to bring this about greatly hinders the heating power being effective. If the radiator is fixed *near* a wall, and the distance rendered less by the adoption of a marble or other top, the hot air will pass through the narrow space with high velocity, and get up to the ceiling before much cooler air has mixed with it. On no account, therefore, cover the top of a radiator, nor adopt a form which has a projecting or domelike head, which is wrong in principle and not more ornamental than many of the radiators on the market whose lines and finish at the upper ends of the sections are all that can be desired.

As the catalogues of makers of hot-water apparatus still show the old-fashioned coil or battery of pipes covered with ornamental, perforated iron cases, a word may be said with a view to hasten the burial of these monsters. A battery of pipes is first fixed near a wall, and after this is done a large cast-iron case is placed over them. This case, like the drawing-

room radiator, must have a marble covering in the ancestral mansion, and the top is consequently air-tight. If the air can get in through the perforations at all, and very little can owing to the friction encountered in passing through such small holes as are generally provided, it is first warmed and then pressed forward so as to make its exit through the perforations near the level of the marble top. Now just where the hot air wants to get out, it meets with the back pressure of the cooler air outside, hence the circulation through the ornamental case is reduced to a minimum, and what air escapes is so hot as to rise quickly to the top of the room or corridor as the case may be. The wall at the back of the pipes receives strong heating, and much warmth is diffused through it and probably lost. If a battery of pipes is thus covered, the deposit of dust not only causes the warm air escaping to have a stuffy, musty odour, but the effective heating power is further greatly reduced. It must not be inferred from the above remarks that coils or batteries of pipes are viewed with disfavour—on the contrary, they can be made most effective heaters—it is the covering of these with a case, especially if closed at the top by a marble or other slab without perforations. If an iron case is desired to cover a coil, let it have perforations not less than one inch square, and let there be *a large perforated surface on top*. In addition to this, the front should be clear and open from 3 *to* 4 *inches above the level of the floor in order that the cold air may get in at the bottom*. The perforated front should be so fixed that it can be removed without difficulty, so that the pipes can be cleaned frequently. There is no question that the modern radiator is much more sanitary, as well as a much more effective heater than the old boxed-up coil.

CHAPTER XIII.

HEATING BY HOT AIR, ETC.

THERE is another method of indirect radiation or heating by hot-water pipes which must receive consideration. This method involves the use of a large battery of pipes or radiators massed together in one room in the basement of a house. Cool, fresh air from the outside is admitted to this heating-chamber, and, after being warmed, it is led through channels or ducts either inside the walls as in the case of a house built for the purpose, or fixed in corners of the rooms to carry the warmed air from floor to floor. The gratings through which the air passes into the rooms can be fixed either in the floor or at one side of the room in the skirting. It is most wasteful and costly to fix a battery of pipes under the floor of each living-room because the loss of heat, the extra expense, the difficulty of cleaning the apparatus, and other considerations relating to the structure of the house make the plan altogether unfeasible. The objections once raised as to the unsightly character of radiators, if they ever had weight, are now dead and obsolete. The common-sense view that what is most useful as well as comfortable can be made ornamental prevails, but, as already mentioned, many radiators on the market are highly artistic in finish, if not elegant in design. If the plan of distributing hot air into the rooms of a house is to be manageable and workable by a servant, the air must be warmed in a room in the basement. A furnace similar to Fig. 32, page 180, may be used, or another form, Fig. 59, which will enable the

back of the boiler being in the heating-chamber, and thus add to the heat of the hot-water pipes or coils, whilst the two sides will be bedded in the parting wall. If Fig. 59 is used for this purpose the makers should be asked to construct it so that it shall have extra coke supply. On no account must the furnace doors, coal supply or damper be either in the air-chamber or connected directly with it. It is not possible to take too great precautions to make sure that neither sulphur dioxide nor any other deleterious gas gets into the air supply. If there is an appreciable vacuum in the heating-chamber, and the full pressure of the outer air exists against the doors of the furnace, the tendency will be for air and other gases to pass through any cracks or interstices in the brick-work or masonry between the furnace-room and the heating-chamber. In view of the frequent changes of pressure which will exist in the heating-chamber itself, it may be as well to point out here that it is best to let the pressure of the outer atmosphere exercise considerable power at the end where the fresh air comes in. To effect this, the inlet for the fresh air should be larger in area than the *combined areas of all the outlets to the various floors.* If this is the case there will not be much difference in pressure between the air outside and that in the heating-room, excepting of course the pressure corresponding to the heat which has been absorbed by the air from the hot-water pipes. The part or whole of the heater exposed in the furnace-room will counter-

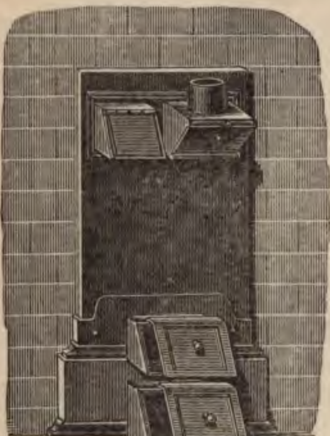


FIG. 59.—Elevation of Boiler and Furnace.

act the lesser pressure due to heat absorbed. In this method of heating great care is necessary in distributing the warmed air, so that a fair share shall pass into every room. Too much stress cannot be laid upon this injunction. Special attention must be given to the air supply of the living-rooms, halls and passages on the ground floor. The ducts must be large, no sharp bends must occur, nor must the air be led through horizontal channels. Unless the headroom in the basement is considerable, 8 feet or more, it will not be possible to get much pressure upon the air supply to the first floor. The ducts or channels should in each case be equal to an area of 144 square inches, and rise as direct and vertical as possible from the heating-chamber. If the heating-chamber is not situated near the centre of the house, it is almost impossible to get this direct air supply, and the value of the system is much impaired in consequence. It is possible to carry a "lead" so as to fix a small battery of pipes directly under a room which is too far removed from a heating-chamber, but it is an expensive and wasteful arrangement, and it is best in that case to fix a radiator in the room itself. It has been stated in the last chapter that it is necessary to have the heating medium as near as possible to the floor, and, better still, to have it under the floor level. It will be seen, therefore, that it is not advisable to fix the inlet grating for fresh air in the side of the wall or above the skirting. On the contrary, if it is fixed vertically it should not only reach the floor, but descend below it somewhat with a slanting front so that the cold air on the floor may be drawn into the ascending current. The grating should have large apertures not less than $1\frac{1}{4}$ inches, and 2 inches would be better, so that little friction would be encountered by the air coming into the room. It is much the best plan to admit the warm air through the floor rather than by a grating in the side of the wall, only the size of the floor grating must be duly considered. If the size of the inlet grating is inadequate and the openings are themselves small, the air coming in may rise

with some velocity, and the tendency will be to get to the ceiling without much admixture on its way. If on the other hand the warm air gets into a room by a grating which is not less than 3 square feet in area, with perforations of considerable size, the air near the floor will so mix with the warm air that the stratum of air at the floor level will not be more than 8° less than it is at the ceiling. *The secret of success is to have the warm air coming up through a long, open grating*, and when this is provided the grating is best fixed in the floor. Care should of course be taken in fixing this grating that it can be raised easily and kept thoroughly clean.

As the air pressure at the back of the warm supply will be so small, for we are dealing with a warm-air supply working by natural means and without any mechanical aid, it will be seen that if a door or window be left open through which the force of a breeze or wind outside comes into a room or into a hall, it is quite possible that the warm air will be driven back upon the heating-chamber. If the fresh air supply happens to be fixed upon the side of a house where the wind exercises suction when it blows from a certain quarter, and the door of the house is so situated that the wind in question blows into the hall or into any other rooms which may have their doors open, it is possible that the warm air will not only be prevented from getting into the hall and other rooms concerned, but it may actually be driven out through the fresh air inlet. The action of the winds must, therefore, be carefully studied, and if they exercise suction upon the air inlet on the outside, this suction should be prevented. Precaution should be taken that no undue pressure shall be exercised when the outer doors are opened. Double doors should be fixed, and a small lobby formed so that a person before entering the hall shall shut the outer door. It is well to treat the back door in a similar way if it is exposed to the action of the wind. As long as the temperature of the air outside is below 50° F. no window should be opened in the ground floor rooms—at any rate the

window must not be opened widely enough to back the warm air coming up. If sufficient warm-air supply is possible it is best to rely upon this, and not to open a window. When, however, through some accident the pipes have got very hot, and it is not possible to endure the air coming in, fresh cool air can either be admitted from the floor of the heating-chamber or a window can be opened somewhat. As long as the heating coil maintains an even temperature the supply can be easily regulated. Owing to the very variable temperatures experienced during one week in this climate the supply of fresh air by the main inlet should be so large that, on a sudden rise of temperature, a considerable portion of the heated air could be expelled through a flue or shaft into waste. If each room is provided with a regulator to cut off the air supply, and this is done because the temperature of the air has increased suddenly, it stands to reason that the air supply to the other rooms will become still hotter. This is one of the disadvantages of the system. If again other room inlets are also closed, those left open will send in air at a very high temperature. To make the system as workable as possible some safeguard against a sudden increase of temperature upon the air outside must be provided. To fix a separate cool air duct, or to arrange the one from the hot air so that cool air can enter at the bottom by moving a lever, may help matters somewhat, but owing to the want of pressure upon the air coming into the living-rooms such a provision will be of little practical value. The best plan is to provide a large duct near the top of the heating-chamber which communicates with the outside air. This duct must have a door which will *close air-tight*, otherwise much fresh air will pass away when it is required in the rooms. If such an arrangement is furnished, the air supply to the rooms, when once properly gauged and apportioned, can remain as such and be rarely altered. The person in charge can tell by a thermometer hanging in the heating-chamber, and whose graduated stem is visible in the furnace-

room, whether the air supply is too hot or otherwise, and open the waste duct if necessary. A little care and forethought will enable the caretaker to manage matters satisfactorily if this safety valve, this outlet duct, has been provided. The outlet should not open wide enough to cause too much heated air to escape, but, on the contrary, there should be enough pressure in the heating-chamber to work the air inlets on the ground floor.

The next consideration is what should be the temperature of the warmed air as it enters the rooms. This at once leads to the question of how much air will be required. In answering these questions the supply to the living-rooms should have first consideration. It has transpired already that the chief difficulty lies with the ground floor supply, owing to lack of pressure. Attempts should be made, therefore, to send as large a volume as possible into these rooms. If this is done the initial temperature of the air leaving the heating-chamber need not be so high. The air entering the room must be of sufficient temperature to supply the loss of heat due to windows, walls, etc., especially the loss due to outside walls with a north or east aspect. After this has been done the room must be comfortable, and the thermometer should indicate a temperature of 62° three feet above the floor, whilst the temperature of the air at the floor level ought to be 57° or more. It should be remembered, too, that the lower the temperature the warm air enters the room the less will be the velocity of the air as it rises in the room itself and the less will be the volume which gets to the ceiling without much admixture with the cooler air below. Taking all these points into consideration, the temperature of the air as it leaves the heating-chamber should not much exceed 70° F. if it can be avoided, even in the winter when the outside thermometer stands at or below 40° F., and 65° ought to do when the outside thermometer is at or above 50° F.

Having made the necessary adjustments for the supply of

warm air to each room on the ground floor at the heating-chamber end, attention can be directed to the ducts conveying the air to the first floor and any other floors which may be above it. If the height between the ground floor and the one above is 10 feet, there will be an increased ventilating power upon the air inlets on the first floor corresponding to the difference in temperature between the warmed air and the cooler air outside. If the warmed air is at 72° F. and the air outside is at 42° F. a column of warmed air 10 feet high will be raised with a pressure equal to ·7 of an ounce per square foot, equivalent to a velocity of 4·4 feet per second in the open. On account of the considerable friction which the air will encounter, it will be seen that the ducts to the first floor should not be less than 18 × 6 inches or 12 × 9 inches. By adding another 10 feet, or carrying the ducts to the second floor, the increased pressure will be doubled, hence the channel for the air supply can be of less area than for those to the lower floors. It is well to remember that if there is only a ventilating pressure equivalent to a column of 5 feet of warmed air to the level of the first floor available that this will only give rise to a velocity of rather more than 3 feet per second in the open air, hence the ducts must be large, and sharp bends in the ducts and horizontal channels must be avoided, else the arrangement will not be workable. By introducing the fresh air inlet at the lowest point in the basement the ventilating pressure will be increased, because, although the battery of pipes may not rest upon the floor of the heating-chamber as it would be below the return to the boiler, the very appreciable radiations shot below the battery even to the floor level will add much to the heat of the air, and so give rise to a longer column of warm air and a corresponding ventilating force.

The practical heating engineer will observe that *one very important factor has been omitted*, and that no notice has hitherto been taken of the ventilating force due to the column of warm air in the chimney or other flue forming the outlet of the

room. This has not been ignored, but it is best to consider the delivery of warm air into the rooms of each floor separately, and distinct from the outlet conditions. The air supply to the rooms on the ground floor should be workable whether they have their doors closed or whether they are open, and if windows are open on the landings or in bedrooms whose doors are not closed, so that the hall is over-supplied with air from above, the warm air supply to the living-rooms must not be much hindered. The foregoing arrangements are suggested with a view to making the system as workable as possible.

With regard to the outlets, the same form already recommended in the case of direct heating by radiators can be adopted. If a fire-place is fixed in the room the ordinary outlet through the grate can be used, but the chimney-breast ventilator mentioned on page 30 is much to be preferred for the reasons already given. If the hot air is intended to warm and ventilate the apartment without recourse to a fire in cold weather or indeed to a fire at all, if possible, the chimney-breast ventilator must be larger than that used in conjunction with a fire, and of about the same area as the flue itself. It should be capable of nice and easy adjustment, fitting accurately when closed, so that in very severe weather, when the room is not in use, it may be shut completely in order to husband the warm air at command.

This system is workable in the majority of houses, but the same conditions which conduce to the formation of smoky chimneys exercise a baneful influence upon it. If the staircase in a house is of the "well" pattern and ascends to a considerable height, there being two or more floors of bed-rooms, and the chimney-flues of the living and bedrooms are in the outer walls and cold, great care must be taken that the "pull" upon the air in the hall does not cause a down-draught in the flues of the living-rooms whenever a door is opened, because if a down-draught is once established the warm air will be forced through the crevices around the windows and the fresh air supply will

be backed even after the doors of the rooms may have been closed. In a house so arranged the "well" staircase may be compared to a chimney-flue of huge dimensions in which the friction of the air as it moves upward is practically insignificant. If there are windows and outlets to the roof or a lead flat the air escaping through the interstices around the sashes or lights will be of immense volume in cold weather, although the windows or lights may be closed. This state of things will give rise to two evils. In the first place the air passing into the hall through the duct on the ground floor will be subjected to unnecessary and great tension, so that it will scarcely be possible to regulate it aright, the result being that, whether too much gets in or too little, there will be such an upward movement and partial vacuum formed that the ventilating force in the hall will be greater than that in any flue in the outer wall, except probably one in a small room having a sheltered and warm aspect.

If a house so arranged has been built with warm air ducts complete, and the trouble mentioned has been experienced, the hall had better be kept as cool as possible unless the staircase will admit of being shut off from the second floor by a glass partition and door so as to divide the height into two separate air columns and reduce the ventilating pressure upon the hall. Another source of much trouble, as in the case of smoky chimneys, is the action of the wind both upon the top of the chimneys and outside the windows of rooms. Good chimney-pots should be used which will not prevent some suction in summer but will not allow the wind to cause intermittent currents and down-draughts in the flues.

The following is a modification of the above system. In this case it is best, as indeed in the former case also, that there shall be a fairly wide hall, and that there shall be a basement underneath in which the battery of pipes shall be fixed. Provision should be made for the introduction of fresh air as low as possible beneath the heater, but it is not essential that

there should be a waste hot-air channel for the purpose of working off the unnecessary and extreme heat which may occur in the heating-chamber through extra firing or sudden increase in the temperature of the air outside. This hot-air arrangement is useful when the tenant prefers to use fires in the living-rooms and only employs the hot air to keep those at a reasonable temperature, 50° to 55° perhaps, in which no fire is lit. The temperature of the air in the hall will be very much the same as that in the living-rooms (without fires), whilst in cold weather the air in the bedrooms will be 3° to 5° lower. The furnace can be of the same pattern and fixed in the same manner as that mentioned above—care being taken that no deleterious gases can get into the heating-chamber, whilst as much as possible of the boiler and furnace is inside to warm the fresh air. The basement under the hall forms a good heating-chamber, and the pipes should extend throughout the greater part of its length. By fixing a grating in the floor of the hall on either side next the skirting, one being for the cold air to descend and the other for warm air to ascend, rapid circulation will take place, with the result that the air in the hall and in landings above will be warmed. To make sure the cool air shall descend one grating a wood partition is fixed underneath the side of a grating farthest from the skirting and reaches from the top of the heating-chamber to within 8 inches of the floor. The cool air will thus flow under the battery of pipes, become warmed in the process and ascend freely through the other grating. Providing the house is of one or two storeys only the rooms on the first and second floors can be warmed by placing two gratings of large dimensions in the walls next to the landing or corridor. One of these gratings, 18 × 12 inches, is fixed so that the top rests against the ceiling, and the other in the skirting, so that its bottom rests upon the floor. When these gratings are open the cold air will flow out of the bottom, and the warmer air will enter near the ceiling and the room will be kept at a reasonable temperature. The ventilator near the ceiling may be dis-

pensed with if a fanlight is fixed over the door of the bedroom. The fanlight may be pivoted in the centre of its height, and, if the area is considerable, it will not only be serviceable when the heater is used, but in hot summer weather a breeze or current may be made to pass through the room into the corridor and out of one of the windows. Fanlights over the doors are more serviceable than ordinary ventilators. It will be noted that this arrangement will work best when the heating from the battery of pipes is confined to the passages and bedrooms, but there will be no difficulty in carrying some of the warmed air through channels to any or all of the rooms on either side of the hall, and it will be found very useful in practice. If the grating in the floor of a living-room is large enough, there will be no necessity to have a cold air or downward grating, although it could be done if required, and would certainly tend to keep the air at the floor level at a higher temperature.

There is yet another modification possible, and this is practicable in cases where there is no basement available for a heating-chamber or indeed for the furnace either. The boiler used for heating the greenhouse or conservatory may be further employed in heating coils or radiators fixed in the hall itself, and the bedrooms can be heated in the same way as previously mentioned. It will not be easy to fix so much heating surface perhaps as could be done in a basement underneath the hall, but it is surprising how many square feet can be obtained from radiators fixed in a hall of moderate proportions. If this method is adopted, the tenant should see that all the upstair windows opening to the roof, or on to lead flats, close as accurately as possible. If any one wants much or little air in a bedroom, it will not matter whether the window sashes fit accurately or loosely, because the window can be opened either little or much when the occupant retires, *but it will matter immensely* when the house is being warmed and the temperature outside is less than 30° F. Have all the windows on the second and higher floors, if there are any, very carefully adjusted, else much radiator

surface may be fixed in the hall without the air in the bedrooms in cold weather being very much warmed. The rooms on the ground floor may be partially warmed from the radiators in the hall by fixing gratings in the skirting and a small one near the ceiling communicating with the room in question. If these gratings are regarded as unsightly, they can be hidden somewhat by a table, a chair or a pedestal for a statuette. Sufficient room must be left for the air to move freely, but there will be no difficulty in relieving the sharp outline of the frame of the ventilator or warm air grating. Where the hall is narrow, and this method of heating is selected, it is not so necessary to limit the height of the radiators, which may be single column and 48 inches high if required.

Having noticed as completely as possible all the points necessary to secure a workable delivery of warm air by this system and its modifications, the question may be asked, How do they compare with the direct or partially direct heating method of using radiators in the rooms? The heating-chamber and warm-air delivery is preferable to the direct heating by a radiator in that *more fresh air* can be made to circulate, but if the radiator is of the form and width recommended, and it is sunk a few inches below the floor, it will heat the air at the bottom of the room better, except the inlet from the heating-chamber is fixed on the floor and is of considerable area. By using the direct indirect method suggested, by which fresh air is allowed to get in and fall down upon a radiator, large volumes of air can be admitted when required, and this style of heating is preferable to the air from the heating-chamber, as it is so easily regulated in each room and can be altered as often as necessary *without interfering with the air supply and heating of other rooms*. Not one of these systems can be made absolutely self-acting, and a little supervision and common-sense are necessary. On the whole, however, heating by radiators fixed in the rooms is the most workable and the most easily managed by a servant.

STOVE HEATING.—In some few houses a ventilating stove has been fixed in the basement, so that air may be supplied to the living-rooms and the hall. Such a plan needs only to be mentioned. It is not a desirable method. Sulphurous and other gases are so insidious and get into the atmosphere so readily that it is best to use hot-water pipes to prevent any possible leakage from the furnace. In other and more numerous cases stoves, either ventilating or ordinary, are used for warming halls and passages with or without provision for heating the bedrooms also. There is no question that it is a great comfort as well as convenience to have the hall and passages in a house warmed, if only to prevent the cold blast which rushes into a living-room every time the door is opened in cold weather. If there is a good flue in the hall and the latter is roomy, the landings and the bedrooms can be rendered much more comfortable in cold weather by warming with a stove in the hall. By using the large open gratings mentioned above, one fixed close to the ceiling in the wall of each bedroom adjoining the landing or corridor (or a fanlight above the door), and another like grating fixed in the same wall near the floor level, there will be a continuous interchange of warm and cold air into each room which has its gratings open, and in this way the stove in the hall can be made to do extended and good service. It is possible to partly warm some of the rooms on the ground floor from a stove in the hall so that they could be used temporally in cold weather without a fire being lit, by adopting the same top and bottom gratings, but it is not practical to heat the usual living-rooms in this way. Indeed the volume of air passing up the staircase would be so large that the movement would be rather manifest in any case, whilst in order to warm the living-rooms the stove would have to be so large that the radiation would be unbearable in its immediate neighbourhood unless the hall was of considerable dimensions. Several stoves on the market are of excellent workmanship and design whilst the

escape of deleterious gases has been greatly prevented, but there can be no question that the hot-water heater, whether a separate radiator or a battery of pipes in a heating-chamber, is much more reliable. If a stove is to be used care should be taken to select one that sends in a current of heated fresh air which has been warmed by material in the stove other than iron at a high temperature. At the same time too much thickness of terra-cotta or vitreous substances prevents the heat from getting to the outside of the stove, and the full heating effect is not obtained.

CHAPTER XIV.

HEATING HORTICULTURAL HOUSES AND STABLES.

PLANT FOR GREEN-HOUSES.—The furnace will be first mentioned. As noticed already with regard to heating-chambers, it is an advantage to use the boiler and furnace for directly heating the air in a small green-house. To this end there are furnaces and boilers combined sold by several makers, like Fig. 59, which can be fixed in and through the outer wall in such a way that only the front of the furnace is outside, and no boiler-house is necessary. In order to prevent deleterious gases getting into the green-house the flue pipe is taken from the front as shown in Fig. 59. If an independent boiler is carefully covered with a good non-conductor, like slag wool, on the outside, or even all around if it is not fixed in a wall, the quantity of heat lost will be trifling, and it is questionable whether the risk of cracks through the masonry and the possibility of gases getting into the interior do not militate against boilers fixed in the outside wall, but if the latter is preferred the front should be covered with non-conducting material, because when exposed to the wind in winter the loss of heat is enormous. The chief objection to boilers like Fig. 59 is that they do not provide enough coke space. Independent boilers like Fig. 32, page 180, have this provision, and with a little care it is possible to keep the temperature of the house during the night much the same as it is in the day. Those who do not know how variable the temperature of most green-houses and hot-houses is between 10 P.M. and 6 A.M. little guess why it is that their plants are

looking so sickly perhaps, and appear very lacking in freshness and vitality. If they did, it is possible they would insist upon having the temperature maintained more equably. No matter how extensive the houses may be, or how large the furnace employed, some reliable provision should be made that the coke supply shall last for at least nine hours, and there shall be no need for the gardener to damp the furnace down or shut up all the air inlets so as to keep the fire *alight* until the morning. Where there are a number of houses[1] the owner may have provided against all contingencies by ordering the under gardener who lodges with his chief to see to all the fires last thing at night and first thing in the morning. Boilers like the improved "saddle," Fig. 60, are good heaters but cannot be expected to give even work at three-quarters their full value for more than five hours during severe weather with the usual coke supply. If the gardener is watchful and wishes to see the best done, any boiler may do fairly well. In the suburbs of large cities there are thousands of villas in their own grounds having one or more green or hot-houses, which are attended to generally two or three times a week by jobbing gardeners.

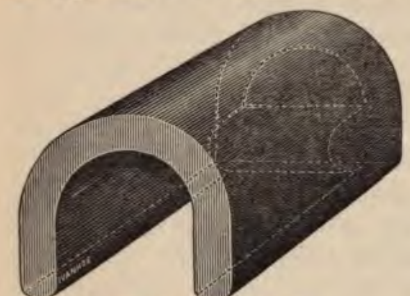


FIG. 60.—Saddle Boiler.

[1] In this case it will be necessary to have a large boiler fixed and housed—not of the independent type, but one cased with brickwork and provided with much more heating surface than can be easily obtained in such a boiler as the upright independent, Fig. 32, p. 180. Whichever form is selected, the Chatsworth, Wentworth, Delta, Tubular, Climax or other, it should be provided with a central funnel or some means of giving a continuous coke supply which shall enable the temperature of the house to be maintained about normal throughout the night.

One of the servants, perhaps, keeps the fire going during the days when the gardener is attending to other houses. It is in such places that furnaces want to be arranged so as to be workable by one who cannot be expected to know much about it, and in cases like this it is absolutely necessary that a reserve coke supply shall be provided, so that the furnace shall maintain a fairly equable temperature for at least ten hours in the winter time. It will probably happen not unfrequently that the servant, having overslept, must attend to the house duties first, consequently it should not be imperative that the furnace shall receive immediate attention in the early morning, otherwise it will burn out sometimes for want of replenishing. Independent or other boilers, therefore, having good storage room for coke are very serviceable, and makers of all forms should try to construct their furnaces so that the coke supply shall *last*. The evils to be guarded against with independent boilers are mentioned in chapter xi., and need not be repeated here. As independent and other boilers used for green-houses, etc., will be wholly or partly exposed to the cold air, care should be taken to cover the exposed parts, piping included, with non-conducting material, so as to save all the heat possible, and in the case of independent boilers place a galvanised iron outer case or hood around them. The method of managing a furnace given in chapter xi. will also apply to those used in horticulture. Where the boiler has to do the double duty of heating a green-house and radiators in the dwelling-house it will be possible to arrange matters satisfactorily, provided the house or the green-house has to be built. The distance between the two must not be unreasonable, and in the case of small supplies ought to be less than 100 feet. Even then if the pipes are not covered with non-conducting material the loss of heat will be great, amounting probably to one-third of the total furnished by the boiler. It should be remembered, therefore, that short leads are most desirable, and that the house and green-house should be as close together as practicable. If the green-house

is separate from the house, and the heating apparatus is to be attached thereto, a neat slant roof with a closed in boiler-house will be found advisable, and a great saving of coke will result. In this case a simple boiler, having a good coke reservoir will be best, unless the grounds are large enough to keep a regular gardener.

It is stated in one of the authorities on warming "*all the air which passes into the chimney should first pass through the fire*". Nothing could be less practical—nothing could be more wasteful, and the gardener who works his apparatus by allowing the least air possible to pass *through the fire* provided he gets the heat required, will use the least coke and with care will not burn more than half the quantity. Be sure, therefore, to let all the air possible enter into the chimney without passing through the fire as long as the necessary heat is maintained—if the flue is low and small in diameter the draught may not be sufficient to allow the air supply to be curtailed much, although this can possibly be done in nearly all cases in cold winter weather with advantage.

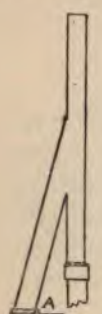


FIG. 61.—Inverted Y Pipe to Flue.

In order to work a small furnace used for horticultural purposes on the same principle as that recommended in chapter xi. when no brick flue is provided and there is simply an iron pipe to carry off the heated gases, it is recommended that the flue pipe be run up without joints or connections where possible, until the point is reached 4 feet 6 inches above the base of the furnace, then a joint is made with an inverted Y pipe, like Fig. 61, the bent side of which is furnished at the end A with a closely fitting valve, which will allow the whole area to be open when required. By thus checking the suction power of the flue pipe, the gases in the furnace need not be subjected to any pressure and the usual damper dispensed with.

The radiators for horticultural purposes are generally four-

inch pipes, although 3, 5 and even 6 inch pipes are sometimes employed. The pipes are usually fixed two deep, the flow pipe being above and the return pipe underneath. Two, three or four single pipes abreast on the same plane branching off from a 4, 5 or 6 inch pipe by means of a syphon like Fig. 62, and terminating in one pipe of similar diameter

FIG. 62.—Syphon with Expansion Joint.

FIG. 63.—Syphon with Expansion Joint.

by the aid of another syphon where the return leaves for the furnace, are preferable to the usual double row of pipes *because there is too much heat in one vertical column, and two or more pipes side by side in the same horizontal plane give much more even and greater heating effects.* Figs. 62 and 63 show syphons provided with a well-known expansion joint suitable

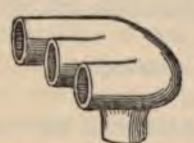


FIG. 64.—Plain Syphon.

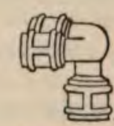


FIG. 65.—Plain Syphon.

for long lengths of piping, but for small houses where such a joint may be unnecessary a syphon like Fig. 64 or 65 will answer the purpose. These syphons can be obtained with inlets and outlets in the same plane or bent at an angle according to whether the flow and return pipes are horizontal or vertical as in Fig. 66, which shows how the flow pipe branches off into three. As soon as the three branches are

formed from the main flow pipe they constitute the return, because this is the highest point of the supply, and as the forward effects are cooling and the water becomes heavier as it travels onward, the system works better on the downward track. When the return becomes a single pipe again it dips under the floor into a trough covered with a grating, and is carried to meet the flow pipe and eventually back to the boiler.

The question as to which is best for horticultural purposes, steam heat or that from hot water, has not been solved satisfactorily because of the conflicting statements made by able

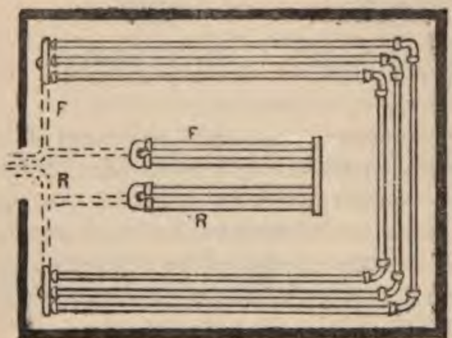


FIG. 66.—Single Piping on the same Plane.

and painstaking observers from the results of their experiments. It appears, however, from these trials that hot water proved to be more economical and effective than steam. From the experiments carried out by others there was not much advantage in either case, only when the effects under the conditions of the most severe weather came to be noted, hot-water heating gave better results and a higher temperature. These experiments are mentioned because one or two points, which should have been duly weighed and considered, seemed to have been ignored, and once these are noted the discrepancies in the re-

sults may be more reconcilable. The following remarks, however, apply chiefly to the effects of steam heating in which the temperature of the pipes is higher than in the case with hot water. When the air leaves strongly heated pipes it rushes up to the top of the house before there is much admixture with the bulk of the atmosphere. In cold weather some of the moisture will be condensed upon the inside of the glass roof, the result being that the heated air ascending to the top will be cooled with great rapidity. This cooling will take place all the more rapidly on account of the air close to the glass being saturated with moisture, and also to the air being pressed up against the glass of the roof with a pressure equivalent to the difference in weight of the column of warm air in the house and the cooler air outside. It will be noted that the condensation of moisture upon the underside of the glass roof, as well as the force of the pressure upon the air against it, will be largely proportional to the severity of the weather outside. It will not need much argument to prove that the more rapid the ascent of the hot air, the more will be the cooling effect at the top of the house, hence it is evident that the lower the temperature at which the pipes are maintained the less hot air will rush up to the glass roof without diffusing itself laterally. It is a well-established fact, as mentioned already, that the heating effects of a radiator are proportional to the force and movement of the air which impinges upon them, and it stands to reason that the more rapidly the warm air is caused to impinge and move over a colder surface, the greater will be the cooling effects. As this is so, it will be seen that the horticulturist should keep the following points in mind when dealing with the question of hot or green-house heating. 1. The pipes should rarely be allowed to exceed 150° F. if the best results are to be obtained, and in calculating the heating surface required for houses in *this* country it will be best to regard 30° or 32° F. as the temperature which is to be furnished without heating the pipes above 150°. Temperatures below 30° F.

may be dealt with by increasing the heat of the water in the pipes. It will rarely happen in this country that the water will require to be more than 170° with such provision. When one takes the heating power of the average small green-house into consideration, it is found that the provision for low temperatures is very inadequate, and the water in the pipes has to be kept as near the boiling point as possible without being able to cope with the severe cold outside. The extra outlay for additional piping is small, and once the first cost has been defrayed there is no further expense entailed. On the contrary, much less coke is required to produce 10,000 British thermal units with water at 150° than is necessary to yield the same number of heat units when the water in the pipes is at 200° F. 2. The pipes must be arranged so as to prevent a rapid current of air moving either against the glass *or indeed in any other direction.* Wherever there is a rapid ascent of air there must be a corresponding descent to supply its place, unless, as frequently happens in hot-house heating, the warm air moving over the glass is so quickly cooled that the circulating effects are nipped in the bud. It is not wise, therefore, to fix the pipes against the walls under the lowest portion of the glass of a slant roof, and in the case of a span they are best distributed evenly and kept a foot or more from either wall. Even then the heating surface should be ample. It is not a good plan either to fix all the pipes as in Fig. 67, where they occur immediately under the edge of the stage on either side and close to the footway through the house, as in this case the tendency is for the warmest air to rise up through the

FIG. 67.—Pipes by Side of Footway.

clear way to the apex of the roof. The pipes will give the best results if they are fixed so that the heating power shall be as evenly distributed as possible. To this end they should not be within 6 inches of the floor, and the ground under the pipes ought to be covered with a non-conducting material like cement.

At this point it is well to consider a mistake which is often made in small heating apparatus, and not unfrequently in larger services for horticultural work. This is fixing the flow and return pipes close together in the boiler, and the return pipe far above the bottom of the boiler. It is a fact that the hot-water engineer in heating a house or block of offices can carry his

FIG. 68.—Pipes Evenly Distributed.

riser to the top of the building and thence heat the rooms on the various floors by the descending leads, whilst if the basement is valuable and he does not want to show the returns, these can be sunk below the floor and connected to the boiler, which may rest upon the floor level. The reason why the water can be carried below the boiler is because the height of the riser is so great that the difference in the weight of the two columns of water—the flow and return—is *considerable*. On the other hand it is known to the physicist that a long test tube held vertically and full of water can be heated by applying a flame rather above half the height, so that the water in the upper part is made to boil whilst that at the bottom is very

little affected or warmed. There is thus no circulation throughout the tube. Where the furnace heats strongest at the top, the tendency of the heated water will be to rise quickly if it can ascend to a higher floor, but this is not possible when the flow pipe at once takes a horizontal direction. However close the flow and return are at the point where they enter and leave the boiler there will be a slight circulation due to the 12 inches of water column, but the physical strain to which the heated flow is subjected in getting on to the extent of the supply is very wasteful of heat. Furthermore, pipes so closely coupled at the boiler do not supply the heat evenly, for it will be found that the lower pipe is many more degrees cooler than the top one *in consequence of the small circulation*. Of course there must be a difference between the temperature of the water in the two pipes—the working difference—but if there is a head of 2 feet instead of one foot, the actual difference in the case of a short length of piping need not be more than 8° in mild and 15° in cold weather. The return pipe should, consequently, enter the boiler in all cases of horizontal work at the very bottom, and in order that the boiler shall do its best work, and not "kick," it is advisable to have a live fire right underneath wherever this is possible. Independent boilers are generally made so that the fire heats the bottom of the boiler.

Giving the flow pipe a slight rise helps matters considerably, but there is nothing like having a good distance between the flow and return, even if the latter pipe dips a little suddenly before it gets to the boiler.

The supports for the pipes should offer as little obstruction as possible to the free circulation of the air, and simple forms like Fig. 69 resting upon wood or cement are recommended. Unless the furnace is large, and the range of houses considerable, it is best to supply the water needed to replenish that evaporated by hand, and soft water is preferable to hard. In the absence of rain water it is a good plan to boil hard water, *and use* the clear liquid after the sediment has settled. The

moisture necessary for the atmosphere of the house is best obtained by making the pipes evaporate some water from troughs fixed upon them. Here again lateral circulation should be avoided. It is far preferable and more effective to evaporate over the greater length of the house than attempt to obtain the moisture required in one part and trust to circulation. Moist air is lighter and much more rapidly cooled than dry air, so that the atmosphere should not be over moist in the first place, and in the second narrow metal troughs at frequent intervals should be used for evaporation. A section through the trough and pipes should appear as in Fig. 70, where the trough is not more than 4 inches wide upon a 4-inch pipe,

FIG. 69.—Support for Hot-water Pipes.

FIG. 70.—Section through Pipe and Water Trough.

and does not prevent the warm air from rising by the sides of the pipes.

3. Another most important consideration is the arrangement of the shelves or stages on either side of the footway. So far as the heating effects are concerned there is no necessity to consider the height to which the shelves may be carried, provided there is a reasonable distance between these and the roof. It must not be forgotten that when the cold is severe outside, the air as it nears the roof is so rapidly cooled that it descends in a stream if the heating power in the house is deficient, or the pipes are allowed to get too cold. The plants on the upper shelves should be very hardy. The chief point to consider is that whatever form of shelves or staging is determined upon, *free way is left for the air heated by the pipes below to move*

upward without difficulty or hindrance, so that the circulation shall not be restricted to one portion of the house. The great fault so general with air-gratings is that the openings are so very small that they offer great resistance to the free passage of air, and a serious mistake in the construction of the woodwork and staging in most green-houses is that insufficient spaces are allowed for the free circulation of the warmed air through them. In some cases the tables on either side of a house are made solid, with the result that the plants near the glass suffer considerably. It has been shown that much heat is wasted when a shelf is fixed which has no perforations, and is arranged as in Fig. 71, where there is simply a space on either side of the benches BB.

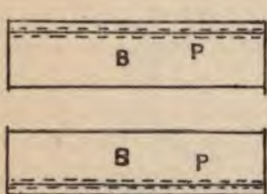


FIG. 71.—Air-spaces by Benches only.

Wherever it is possible, and it generally is with the exception of forcing-houses, the stages and tables should be made of lath work with large perforations. Where extra strength is required the woodwork can be deeper with frequent supports. The gardener will find it so greatly to the benefit of the plants to have a steady and easy circulation that the free movement of the air through the stages and benches should receive his first attention, and it is the lack of this free and easy circulation which accounts for the bad appearance of plants in many houses which are well looked after. The bad arrangement of the pipes in many conservatories is another reason why the plants suffer. The whole subject of the circulation of air in green and hot-houses has never received the attention it deserves, and even to-day it is not regarded as a very important matter by some horticulturists.

With reference to the question of steam and hot water for heating, hot water is preferable as it requires less attention. It is possible to use steam and still keep the pipes at a low temperature, but unless much care is taken in stoking, and a

special boiler is provided, the coal or coke consumed will be much less in the case of the hot-water apparatus. If the same boiler is used for raising steam as is used for hot-water heating, it stands to reason that more coal will be required to raise the steam than would be necessary to heat the water, especially if the latter were employed at a temperature not exceeding 150° F. This is so because all the gases escaping into the chimney must of necessity be at a higher temperature in the case of steam heating at 212° or more than with water heated to 150°. Heating by hot water is, therefore, the most economical. When steam is used for power and the waste can be employed for heating there may be an economy in using it. In such a case the piping had better be fixed as near to the floor as possible, and very evenly distributed.

With regard to the heating surface necessary, it is not at all easy to determine it. There are so many things to be taken into consideration. The lower the house the less it will be subject to the action of the wind. If the house is high and is a lean-to against a high wall, or better still against the south side of a house, the heat required will be much less. Some authorities recommend measuring the superficial extent of the glass in the house, and calculate about one foot of heating surface for every 4 feet of the former. This is a generous allowance if all the precautions mentioned above are duly regarded, and there is a good distribution of the pipes and easy circulation of the air. It must not be forgotten, however, that any carelessness in the finish of the ventilators and door or doors may so reduce the temperature in the house by leakage of cold air from without, that the heating power of the pipes may be sadly deficient. Care should be taken, therefore, to see that there is no jerry building—no warping and twisting of doors and ventilators.

Other hot-water engineers prefer to calculate the heating surface for green-houses from their cubic capacity, and allow 50 feet per 1,000 cubic feet of air space. Much will depend

upon the height of the house from the point where the glass begins, whilst not a little depends upon the nature of the bottom and whether it is a non-conductor of heat or otherwise. The above heating surface is generally ample for green-houses where the heat is not required to be above 65°, but if the walls of the house are low and the proportion of the surface of glass above the average, 60 feet per 1,000 cubic feet of capacity is not too much, whilst 70 cubic feet or more per 1,000 can be employed in a hot-house heated to 80° or more with advantage. The above estimates are based upon the heat of the pipes being kept at 180° F. or more, but it has been shown already that the lower the temperature of the water is the more successful and even will be the heating in the glass-house, and the less coke will be consumed in the furnace. At first thought, therefore, one would be ready to assume that this was a case where the heating surface could be increased to any amount with advantage, because four rows of pipes would not be more unsightly than two. There is no doubt that 100 feet of heating surface at rather over 100° F. per 1,000 cubic feet of air would heat a glass-house much more economically and effectively and with greater advantage to the plant life than 50 feet at 190° F., and the question arises, Is the advantage derived worth the extra expense? Most certainly it is, but a correct knowledge of the difficulties of heating generally must be obtained first in order that the arrangement of the pipes shall be such that the apparatus will be workable in spring and autumn. Horticulturists know well how valuable a little heat is just in the chilly spring and autumn days, and nights especially, but they know also how difficult it is to get their apparatus to work so that it may be used continuously. It stands to reason, therefore, that if it is difficult to keep the temperature in the houses down low enough for the fire to burn continuously under the boiler whilst using 50 square feet of heating surface per 1,000 cubic feet of air, how much more difficult it will be to do this if there are 100 square feet of surface per 1,000 cubic feet of

air employed. It is imperative, therefore, to use the smallest heating surface possible so as to keep the pipes warm enough to work the heater satisfactorily, or *else to be in a position to cut the heating surface down at will.* In other words, the extra heating surface must be so arranged that when the temperature of the air outside is about 50° F. one-half of the heating surface can be cut off. This can be done without much difficulty in the case of a series of houses kept at the same temperature, because when single piping is employed and four, six or eight pipes are used on the same horizontal plane, one or two valves

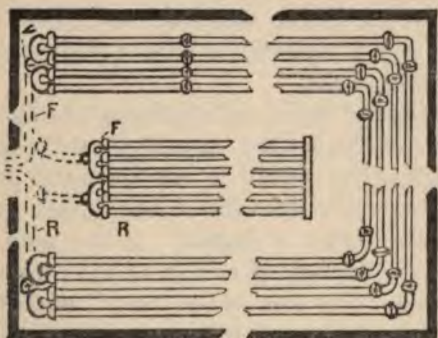


FIG. 72.—Hot-water Pipes Arranged so that Half can be Cut Off.

at the upper end will be sufficient to control the pipes to be cut out of circuit. The pipes in any glass-house or conservatory, however, can be easily arranged, so that one-third or one-half of the heating surface can be cut out. Fig. 72 shows a green-house or conservatory having a flow situated as in Fig. 62, page 247, but there are two branches from it, and these branches are each connected to two-pipe joints. Upon one of these branches a valve is placed for the purpose of cutting two pipes out of circuit, and thus reducing the heating surface by one half, whilst the usual valve upon the main flow will cut off the whole supply if desired.

Experience has shown repeatedly that plants in green-houses, etc., flourish best and look healthiest when the temperature outside is moderately warm, and the heat of the pipes is not above 100°. Of course there are questions of better ventilation being possible, and other points in favour of mild weather, which have to be taken into account, but there is no doubt that houses heated in *cold weather* with ample piping so that the temperature of the water does not rise much above 150° will give the best and most satisfactory results. Provided, therefore, that the furnace is not increased *pro rata* and is only equivalent to two-thirds of the piping used if heated to 190° F., and that the precautions mentioned in chapter xii. are observed, *it is a great advantage to allow a most generous number of feet of heating surface.*

In the matter of valves and regulators, let these be used as sparingly as possible, and their capacity should be considerable. For the single piping method in one horizontal plane recommended by the writer the valve is best placed on the single flow before the syphon is reached. It is a great mistake to place a valve having only 1¼ inch or 1½ inch aperture upon a large flow pipe. The area of the "way" through the valve should be of ample size. It is easy to contract the space, but when a rapid circulation is necessary the flow will be checked greatly if the water has to pass through a narrow or constricted orifice.

HEATING STABLES.—For heating stables, hot-water pipes are to be preferred to radiators or batteries of pipes which necessitate the circulation of the air from considerable distances. The pipes should be kept near the floor level, and where loose-boxes occur a good iron grating should be fixed in the door just above the floor so as to allow the cold air around the horses' fetlocks to pass out and be warmed. If possible the grating should be opposite to the tail of the animal, *i.e.*, as far as possible from the manger, so that the breath shall not be influenced but allowed to go up without being involved much

in the circulation towards the hot-water pipes or other heating medium. Stables having a single row of stalls can be heated nicely with two 4-inch pipes. These can be fixed to the front wall, but should be allowed to stand two inches or more from it, so that there may be room for the circulation of the heated air. A stable should not be heated unless the temperature of the air outside is below 50° F.

APPENDIX I.

SOME ELECTRICAL CONDITIONS OF AIR.

THE writer has elsewhere referred to the electrical conditions produced in the air of large buildings where sudden up and down movements resulted owing to the top or outlet ventilation being largely in excess of the bottom or inlet air. The matter was dealt with "vaguely" because there was no data to go upon which would enable one to point out how much electricity or electrical effects were produced. All that is known at present is that it is not possible to give rise to any movement in air without some electricity being formed. Recent researches into radiations of very high frequency show that it is scarcely possible to generate one form of radiation without, by sympathy or otherwise, giving rise to radiations of different wave-lengths and properties. How far these radiations and electrical or other effects alter the statical conditions of the atmosphere it is not easy to say, but that they do exercise certain effects upon the human, and indeed upon the animal, economy generally seems to be somewhat conclusively proved. There is no question probably at this time that the peculiar effects experienced just previous to a thunderstorm are electrical, although as to the nature of the phenomena we are not by any means so certain. The peculiar and distressing experiences noted previous to the coming of a hurricane or tornado in warm climates are also well known, and it is not difficult to surmise that these effects can easily precede the coming storms on account of the great speed with which electrical or other vibrations travel.

The extent to which air may be ionised by electrical forces which are purely mechanical is perhaps not great, but it is known now that certain compounds of radium and other radio-active substances affect the ionisation of air. The experiments carried out by Wilson, *Proc. Camb. Phil. Soc.*, 1901, 1902; Rutherford and Allen, *Phil. Mag.*, 1902; McClelland, *Sci. Trans. Royal Dublin Soc.*, 1903, though they are inconclusive as to the exact sources of the ionisation effects, point distinctly to some radio-active substance disseminated through the atmosphere.

The chief interests from these experiments so far as the heating of dwelling-houses or public buildings is concerned are two. 1. As to what extent these electric conditions are altered by washing the air as is done by causing it to pass through a screen down which water trickles, or by any other method. 2. What effect is produced when the air either washed or unwashed is heated by radiators, stoves, or other form of heating? In reference to the first question it seems probable that much of the radio-active dust in the air will be removed by such washing, and it is not unlikely that the ionisation of the air will be in great measure destroyed. The effects of washing air with tap water are not to be compared with the washing of air by falling rain. The experiments mentioned by C. T. R. Wilson show that the solid matter in rain water collected as it falls is strongly radio-active, whilst that in tap water is quite inactive. It is not possible to do more in the present state of our knowledge than mention these facts in the hope that the important bearing which they have upon animal life will be more fully studied. If the radio-active dust in the atmosphere has anything to do with the freshness and salubrity of the air, then the less the air is washed with tap water or with rain water which has not been recently collected the better.

So far as the answer to the second question is concerned there is probably equally as little light upon the matter. It is likely, however, that what tends to suddenly cause the molecules of air to fly asunder must alter the static condition of the body of air and should be avoided. Hence very hot surfaces should not be

used for heating, especially those whose temperature is excessive, such as metal plates, iron stoves, etc. The writer has stated elsewhere that a temperature of 150° F. should not be exceeded, if possible, for steam- and hot-water pipes, and the peculiar smelling effects of air heated by hot iron are not sensible at that temperature. These effects may be and are more due to strong heat than anything else, and the subjection of ionised or ozonified air to a temperature of about 150° F. ought not apparently to give rise to any appreciable alteration or to destructive results.

Dr. Napier Shaw referred to the ionisation of air in his evidence before the Select Committee of the House of Commons on Ventilation, but he was not able to state anything definite as to what effect the treatment of air in the modern systems of ventilation exercised upon its electrical activities.

Since the above was written the radio-activity of ordinary matter was discussed at the Cambridge Meeting of the British Association. Professor J. J. Thomson maintained that all matter was radio-active, and if this is so all the dust in air will cause some ionisation. It was pointed out that the air in high regions contained many ions, but these were present because the *life* of the ions there was so much longer. In a dust-laden atmosphere such as that in towns the life of the ions is very short but the production is rapid. It follows, therefore, that if air is washed and the radio-active matter removed, no further ionisation can proceed, and as the *life* of the ions is so short, under the circumstances, the air is immediately de-ionised in the process.

APPENDIX II.

CALCULATION OF THE VENTILATING POWER OF CHIMNEYS.

THE writer prefers to use the method of calculation which he has adopted in the first chapter and elsewhere in this and other treatises, but it is possible to estimate the velocity of air movement in chimneys in another way. The following remarks by Dr. Billings[1] show how he does this: "The velocity in feet per second of falling bodies is about eight times the square root of the height from which they have fallen expressed in feet, and the formula for determining this is $v = c\sqrt{2gh}$. . . . The difference in pressure is found by multiplying the height from the opening at which the air enters the flue to that from which it escapes by the difference between temperature outside and inside, and again multiplying this product by $\frac{1}{491}$. The formula for the theoretical velocity then becomes

$$v = 8\sqrt{\frac{(t\text{-}t') \times h}{491}},$$

in which t is the temperature in the chimney, t' the temperature of the external air, and h the height of the chimney.

"Suppose, for example, that the temperature in the chimney is 100°, that of the external air 40°, and that the chimney is 50 feet high, we shall have

$$v = 8\sqrt{\frac{60 \times 50}{491}} = 8\sqrt{6{\cdot}11} = 20$$

nearly, or the theoretical velocity would be 20 feet per second.

[1] *Ventilation and Heating*, pp. 139, 140.

"This theoretical velocity will be diminished by friction, by angles in pipes and flues, and by eddies or counter-currents, and on the other hand it may be increased by the aspirating effect of wind passing across the top of the flue."

The value of such a calculation may be gathered by the concluding remarks of Dr. Billings, but these do not fully convey the uselessness of the knowledge obtained. Whether we calculate from the table on page 266 or from that given by Professor Carpenter[1] as the weight of air at different temperatures, and obtain the velocity resulting from the difference in pressure between the air outside and the smoke in the chimney from the table of wind pressures and velocities in Carpenter on page 55, that on page 267 of this treatise, or that calculated from Hutton's experiments given by Box,[2] it will be found that the theoretical velocity from the above formulæ is greatly diminished by the air moving upon itself to get up the velocity.

Taking the example quoted by Dr. Billings the chimney is 50 feet high, then 50 cubic feet of air outside at 40° F. weigh 3·97 lb., and 50 cubic feet at 100° weigh 3·55 lb. (Carpenter's table). The difference is ·42 of a pound. Turning to Carpenter's table on page 55, or on page 267 of this treatise, a pressure of ·42 of a pound per square foot is equivalent to a wind moving at about 14 feet per second in the open. The pressure which is thus lost in getting up the velocity in the open air has a very important bearing upon the movements of air generally, and this accounts for the difference in velocity between the 20 feet per second found by Dr. Billings and the 14 feet per second calculated by the author's method.

[1] *Heating and Ventilating Buildings*, p. 521.
[2] *Treatise on Heat*, p. 290.

APPENDIX III.

Weight of 100 Cubic Feet of Air in Pounds at Different Temperatures and under Different Barometrical Pressures, and Increase in Volume of 100 Cubic Feet of Air by 10° of Heat above 32° F. (0° C.).

Temperature on Fahrenheit's scale.	Weight of 100 cubic feet of air in pounds, barometer 29 inches.	Difference between 10° in temperature in parts of a pound.	Weight of 100 cubic feet of air in pounds, barometer 30 inches.	Difference between 10° in temperature in parts of a pound.	Weight of 100 cubic feet of air in pounds, barometer 31 inches.	Difference between 10° in temperature in parts of a pound.	Difference in weight of 100 cubic feet of air due to a rise or fall in the barometer of 1 inch.	Expansion of 100 cubic feet of air by being elevated in temperature 10° F.
30	7·838	—	8·108	—	8·378	—	0·270	—
32	7·805	—	8·074	—	8·343	—	0·269	100·00
42	7·680	0·158	7·945	0·163	8·210	0·168	0·265	102·04
52	7·530	0·150	7·790	0·155	8·050	0·160	0·259	104·07
62	7·387	0·143	7·641	0·149	7·895	0·155	0·254	106·11
72	7·247	0·137	7·497	0·144	7·747	0·148	0·250	108·14
82	7·113	0·134	7·358	0·139	7·603	0·144	0·245	110·18
92	6·984	0·129	7·225	0·133	7·466	0·137	0·241	112·22
102	6·861	0·123	7·097	0·128	7·333	0·133	0·236	114·25
112	6·740	0·121	6·972	0·125	7·204	0·129	0·232	116·29
122	6·624	0·116	6·852	0·120	7·080	0·124	0·228	118·32
132	6·512	0·112	6·736	0·116	6·960	0·120	0·224	120·36
142	6·403	0·109	6·624	0·112	6·845	0·115	0·221	122·39
152	6·299	0·104	6·516	0·108	6·733	0·112	0·217	124·43
162	6·198	0·101	6·411	0·105	6·624	0·109	0·213	126·47
172	6·099	0·099	6·309	0·102	6·519	0·105	0·210	128·50
182	6·003	0·096	6·210	0·099	6·417	0·102	0·207	130·54
192	5·910	0·093	6·114	0·096	6·318	0·099	0·204	132·58
202	5·820	0·090	6·023	0·093	6·223	0·095	0·201	134·62
212	5·735	0·087	5·933	0·090	6·131	0·093	0·198	136·66
222	5·651	0·084	5·846	0·087	6·041	0·090	0·195	138·69
232	3·569	0·082	5·761	0·085	5·953	0·088	0·192	140·73
242	5·489	0·080	5·679	0·082	5·868	0·085	0·189	142·76
252	5·412	0·077	5·600	0·079	5·786	0·082	0·186	144·80
262	5·337	0·075	5·522	0·078	5·706	0·080	0·184	146·84
272	5·264	0·073	5·446	0·076	5·627	0·079	0·181	148·88
282	5·193	0·071	5·372	0·074	5·551	0·076	0·179	150·92
292	5·124	0·069	5·300	0·072	5·477	0·074	0·176	152·96
302	5·057	0·067	5·231	0·069	5·405	0·071	0·174	155·00

APPENDIX IV.

Table of the Velocity and Force of Wind.

Velocity of the Wind.		Perpendicular force on 1 square foot in avoirdupois pounds and parts.	
Miles per hour.	Feet per second.		
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·4	·044	
4	5·87	·079	Gently pleasant.
5	7·33	·123	
10	14·67	·492	Pleasant, brisk.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High wind.
35	51·34	6·027	
40	58·68	7·873	Very high wind.
45	66·01	9·963	
50	73·35	12·300	Storm or tempest.
60	88·02	17·715	Great storm.
80	117·36	31·490	Hurricane.
100	146·7	49·200	Hurricane that tears up trees and carries buildings before it.

APPENDIX V.

THE POSITION OF INLETS AND OUTLETS.

THIS question should be taken as far as possible out of the region of "opinions," because, like every problem of ventilation, it must have a *physical basis absolute and exact.* As far as the present treatise is concerned, the problem will be considered from the standpoint of the rooms in dwelling-houses, but as assembly rooms, schoolrooms, etc., which are ceiled are only rooms on a larger scale, the physics which bear upon the one must bear upon the other. The "opinions" in dispute are strongly advocated, a number of experts stating that the outlets for foul air should be situated close to the floor, whilst others contend that the right place for the outlet is as near to the ceiling as possible. Taking first the case of a room in which a fire is burning and from which the only outlet is the lower end of the chimney-flue, eighteen inches above the floor level, this state of things approximates very nearly to the outlet *at* the floor level. From experiments carried out by the writer the figures show there is great difference in temperature between the air one foot from the floor and near the ceiling of the room. Where gas is used for light, the difference is frequently 20° F. Now this 20° F. represents a very appreciable upward pressure exerted upon the air column lying between the orifice of the chimney and the ceiling of the room. This pressure is entirely independent of the difference between that on the outside atmosphere and that on the air and smoke in the chimney, because it is due to the greater temperature of the air in the upper than in the lower part of the room, and it is something apart entirely from

the ventilating power and must be reckoned by itself. Let us note what would happen if there was no fire-place in the room, and the temperature one foot from the ground was 55° whilst that near the ceiling was 75°. The spaces around the top of the upper sash would act as outlets, and probably the space above the top of the door would behave in a similar manner. Now in consequence of the *pressure* due to the 20° mentioned being independent of the fire,[1] a portion of vitiated and heated air in the upper part of the room will be expelled through the spaces above and around the upper window sashes and door. Were it not for this invisible and unknown behaviour of the heated air in the upper part of living-rooms the atmosphere would be unbearable soon after the gas has been lit. As pointed out in sequel, the lesser heat of the electric light has made the contaminated condition of the air in small crowded living-rooms more manifest, and this was because so much less heat was evolved and so little air escaped near the ceiling. Again, as stated in chapter iv., much the larger portion of the air escapes up the chimney without taking any part in the ventilation of the room, so that the impurities above the flue are only brought down by the ascent of the little air warmed to a temperature sufficiently high to rise above the level of the chimney opening. Under these circumstances, the air at and above the heads of the occupants is one concentrated admixture of impurities, so that it is practically impossible with this downward system of foul air extraction for the persons present to inhale air which is not largely contaminated, both by breathing and by the products of the combustion of gas or oil if these are used. Furthermore, the stagnant condition of the upper air, which has not only to move down *against gravity but against appreciable pressure*, is not only wrong physically but most oppressive to the occupants. This

[1] The author has not seen this pressure mentioned in any treatise on heating. It may be contended that it is neutralised and overcome by the general reduction in pressure in the room caused by the fire, but this is not so because the pressure due to 20° rise in temperature will be still in force, and be doubly active when a door or window is opened.

fact is very evident to those who sit in rooms in spring and autumn when the temperature of the air outside is 50° F. or more. The ventilating pressure of the air outside is small, and though there may be 20° of difference of temperature between the air one foot from the floor and near the ceiling and the volume of air expelled around the upper sash of the window be the same, the atmosphere at the breathing level will be rendered close and oppressive because the ventilating power of the chimney will be so much less than in cold weather.

On the other hand, what would happen if the outlet was placed near the top of the room? The question under consideration is the chimney-flue (with fire) as an outlet. With an effective flue ventilator the excess of heat in the upper part of the room is not so great, showing that more cool and fresh air is raised into the breathing zone. The physical conditions are in harmony with the effective working of the outlet. The extra and independent pressure noticed above is not used to act *against* the ventilating power of the chimney but *to drive the heated air near the ceiling into the chimney-flue*, whilst the spaces around and above the upper sashes of the windows distribute fresh air and act as *inlets* instead of *outlets*. If the supply of air to the room is large and ample, an effective outlet at the top of the room will enable the occupants to breathe air practically untainted, because *as shown by the lesser temperature near the floor level, the air is much freer from impurity.* So far as a room with a fire is concerned, the outlet should be near the ceiling and the physical considerations prove this beyond question.

Let us next take the case of a room with a fire-place having an opening 12 inches from the floor level, and no other opening into the flue, but heated entirely by a hot-water radiator. If the room is high, it will be found that the chimney-flue admits much cold air as well as expels it in cold weather, unless the volume of air coming in is very much larger than usual. This action is due to the chimney-flue being gradually cooled by the outer air getting down into it, and the expulsion of the hot air through the crevices

around the window sashes, etc. If these crevices are fairly large in their aggregate area, the chimney-flue may act almost entirely as an inlet should the suction of the wind as it blows at the ground level favour this. *It is the independent pressure due to the greater temperature of the air near the ceiling which accounts for the foregoing.* The author has experimented repeatedly with radiators, but as there is no space for many figures, the following must suffice to show what the difference of temperature in the room was on a certain day. Temperature outside 34°. Temperature on floor just under window 53°. Temperature on floor farthest from radiator near inner wall 54°. Temperature one foot from floor 55°. Temperature on dining-room table 56°. Temperature by wall 5 feet from the floor 57°. Temperature 6 inches below electrolier 61°. Temperature near ceiling 67°.

The radiator stood 3 inches above the floor and was on the other side of the room from the fire-place, there being no chimney-breast ventilator open. In this case the air was dry, and only one or two persons present, so that the warm air near the top of the room escaped very readily through the crevices above the three large sashes of the windows.

If the outlet was through the chimney-breast ventilator, without a valve and large, and the opening of the chimney-flue above the fire was sealed air-tight, every grain of pressure per square foot would be used up in expelling the vitiated air in the manner which physical science shows is correct and best.

The case of a room heated by hot air will next be taken. The hot air comes through a duct from the basement where air is heated by a battery of hot-water pipes. The hot air is let into the room on one side at a height of 8 feet from the floor and the outlet is 6 inches from the floor. It is found that when the door and window are closed, the volume of air at times coming into the room is practically nil, and the temperature of the air near the floor is very low. There is no fan or mechanical force behind the air, but it ascends "naturally". What is happening? The outlet is too large for the air coming in. The suction which the warm column

of air is to exert upon the room does not come off because the outlet is cooled and lets cold air down instead of taking warm air out, whilst what warm air does come in is driven out through the windows by the pressure of the cold air at the bottom of the outlet. If the outlet acts, it is only intermittent, and the opening of a door may reverse the current. This state of things is physically wrong, the outlet should be near the ceiling, but even then the incoming warm air should have some *certain* pressure behind it.

The next point to be considered is the chief bone of contention between experts. Those who advocate outlets at the floor level may admit the value of the outlet near the ceiling in the case of so-called "natural ventilation". It is when the plenum system by downward propulsion is employed, and the air is heated and sent into a room under pressure, that the outlets should be fixed near the floor, they say. A class-room in a Board School, ceiled, will suit for an example, as this is only an ordinary room on a large scale. The air at a high temperature, say 70° or 80°, is sent in under pressure through a duct 8 feet from the floor, and the outlet is fixed at the floor level, but is really 12 inches above. The hot air sent in immediately rises upward, and a large volume is introduced with a view to place the air in the room under a slightly greater pressure than that exerted upon the air outside, so as to force the air downwards and up the outlets at the floor level. Is this accomplished? No, there are three large windows and two doors and the fresh air escapes around the interstices at a quicker rate than the quantity sent in can cope with, the consequence being that the outlet near the floor level is either inoperative or acts as an inlet. When the latter is the case the 16 feet of hot air column enables the outlet to exert some ounces of pressure per square foot in forcing the air through the crevices around windows and doors, so that the principle is rendered inoperative. Even if the room had no windows and the door could be made air-tight, whilst the hot air came in at 8 feet from the floor and the foul air outlet was near the floor, the breath of the occupants would continually be brought back to be inhaled,

and the air would always be at its worst possible condition for the volume of air sent in. This results because the expired air is hotter and lighter than the atmosphere in the room and rises upward, so that by a reasonable volume of air coming in at the floor level and getting out at the top, as in the case of the Debating Chamber in the House of Commons, the air at the breathing line is practically as good as it is outside the building.

There is another serious drawback to the working of the outlet at the floor level. The air cooled by the windows and outer walls falls down to the floor. *Here the temperature is very low, and there is no chance to raise it*, the consequence being that the feet of the occupants are most uncomfortably cold in severe weather. The idea of placing the outlet on the floor is that this cold air will be driven out by the extra pressure, but as the extra pressure does not exist in cold weather and the outlets are possibly 15 inches high, little if any air passes up them and the idea is not realised. *Let it be understood distinctly that this question of downward propulsion is vastly superior to any natural system in halls where many persons assemble.* You cannot force air into a room without the benefit being felt, but *if the greatest effect and good are to be obtained, it will not be the result of downward propulsion.* The author has found that in churches, heated by hot-water pipes fixed under the level of the floor, the temperature of the air 6 inches above the floor and at 3 feet above was practically the same. This showed that the air at the floor level flowed towards the current of hot air rising from the pipes to supply its place whilst air at a higher level circulated to fill the room vacated by the cold air. From this it can be seen that the heated air should come in either below or at the floor level, so that the cold air from the floor may be aspirated into the ascending current and be warmed thereby. And, as stated already, the outlet should be at the highest point and, if possible, in the centre of the room, which if long might have two or more outlets, then the whole available ventilating pressure will be utilised in expelling the vitiated air.

It will be best to anticipate some apparent difficulties in having

the outlet near the ceiling. First, where a fire is burning in a room and a chimney-breast ventilator is used. Will not the air which is warmed near the fire rise up in front of the mantel and immediately make its exit through the flue ventilator without doing any good? This would be the case largely, doubtless, if it were not that the cold air moved forward across the room at the floor level to supply the fire and the hot current rose in front of the mantel. In consequence of the air in a room being confined somewhat and the circulation being comparatively rapid, the hot air in front of the mantel passes into the centre of the room before it ascends 3 feet, and eventually circulates to supply the place of the cold air flowing towards the fire at the floor level.

Secondly, if the fresh air inlet of a room warmed by hot air sent in under pressure was at the floor level, would not the air rise to the ceiling? Not if provision was made for the cool air on the floor to mix with it. In all cases where the outlet cannot be in the centre of the room, it should be on the other side from where the hot air enters. Dr. Billings states that hot air from the floor level may rise to the ceiling, flow across it and enter the outlet on the other side. This is not likely and is contrary to physical law, but if it were true it would be an additional reason for sending in heated air, as always advocated by the author, through a thousand inlets at the floor level if possible. It is the method adopted in the Debating Chamber of the House of Commons, and the best possible. If a house was heated by the upward plenum method, it would not be at all difficult to admit the warm air in more than one part of a room.

We now come to the consideration of downward propulsion in reference to the supposed even mixture of the air through the outlet being near the floor. Let us suppose that a school-room is 30 feet long and 20 feet broad and there are three windows. The inlet grating for hot air is in one end of the room in the inner wall, and the outlet immediately under (this is the position of the gratings in a room in a well-known building heated by downward propulsion). What will happen? The cooling ef-

fects of the windows cause a current to move toward them from the top downwards. The hot air getting through the grating moves forward, therefore, to the windows, but the cooled air does not circulate direct to the outlet on the floor, but *flows over the whole room*, because it will be found that the temperature varies very little over the whole floor. If circulation did take place direct from the hot grating to the window and back from the window to the outlet, two-thirds of the room would be without any air movement, and the installation would be ineffective. This want of diffusion is one of the great defects of the system, especially where, as is generally the case in a large room, there is only one inlet and one outlet, and these are frequently placed at or near the end of a long room. So far as the distribution of the air is concerned, therefore, it is easier to do it by the upward propulsion than by the downward propulsion method. Physical considerations are entirely against the outlets being placed at the floor level, whilst they favour the outlet being in the highest part of the building. Those who advocate the outlets being placed at the floor level quote the experiments carried out by Mr. W. R. Briggs of Bridgeport, Conn., as favouring if not proving the best means of introducing fresh air and removing the deleterious products. Mr. Briggs used a model into which hot air, rendered visible by smoke, was introduced and expelled at various points. Diagrams of these experiments are given by Professor Carpenter,[1] the conclusion being that if the warm air is introduced 8 feet from the floor, and the outlet is fixed immediately under the inlet at the floor level, the best results are obtained. The author has pointed out emphatically the absolute importance of preventing the air leaving a radiator at a high temperature, because it rushes up to the ceiling and forms a layer of hot air there when the opening to the fire is the outlet. The more rapidly the hot current ascends the thicker will this hot air stratum become, and common-sense tells us, without experiments, that the position recommended for

[1] *Heating and Ventilating Buildings*, pp. 57, 58.

the inlet and outlet is the one where the inlet air is bound to descend to the level of the outlet. But we are not dealing with air of the temperature of smoke or with hot currents which *are physically bound to rise to the ceiling rather than mix and circulate with the air stratum near the floor level.* If the warm air is introduced at the minimum temperature necessary, and through a large grating, so that the velocity does not exceed 3 feet per second, the condition of things will be very different from that experienced in the experiments carried out by Mr. Briggs, when the inlet was at the floor level and the outlet near the ceiling. If the diagrams mentioned show the effects of the smoke used by Mr. Briggs, the experiments are as misleading as they are valueless. The conclusions arrived at by Mr. Briggs are correct so far as obtaining a perfect mixture of the impurities, and making sure that the heads of the occupants shall be always surrounded by a vitiated atmosphere, but Mr. Briggs must be credited with the desire to obviate such a state of things.

When the question of downward propulsion is applied to churches and buildings open to the apex of the roof, and having much outlet space through cracks and fissures, the plenum system by downward propulsion must be a failure, because the hot air will escape without being of use to the persons assembled, whilst their feet and legs in winter will be frigid.

The foregoing pages on the "position of inlets and outlets" have been relegated to the appendix because the question required considerable space for discussion, and was best left out of chapters iv. and v. on that account. The subject is, however, of much importance and worthy of the fullest elucidation.

Some of the above arguments against downward propulsion by the plenum method were brought forward by the author in his evidence before the Select Committee of the House of Commons on the Ventilation of the House.

INDEX.

The thick figures indicate the most important references.

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